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**WEEKLY** 7 January 2023

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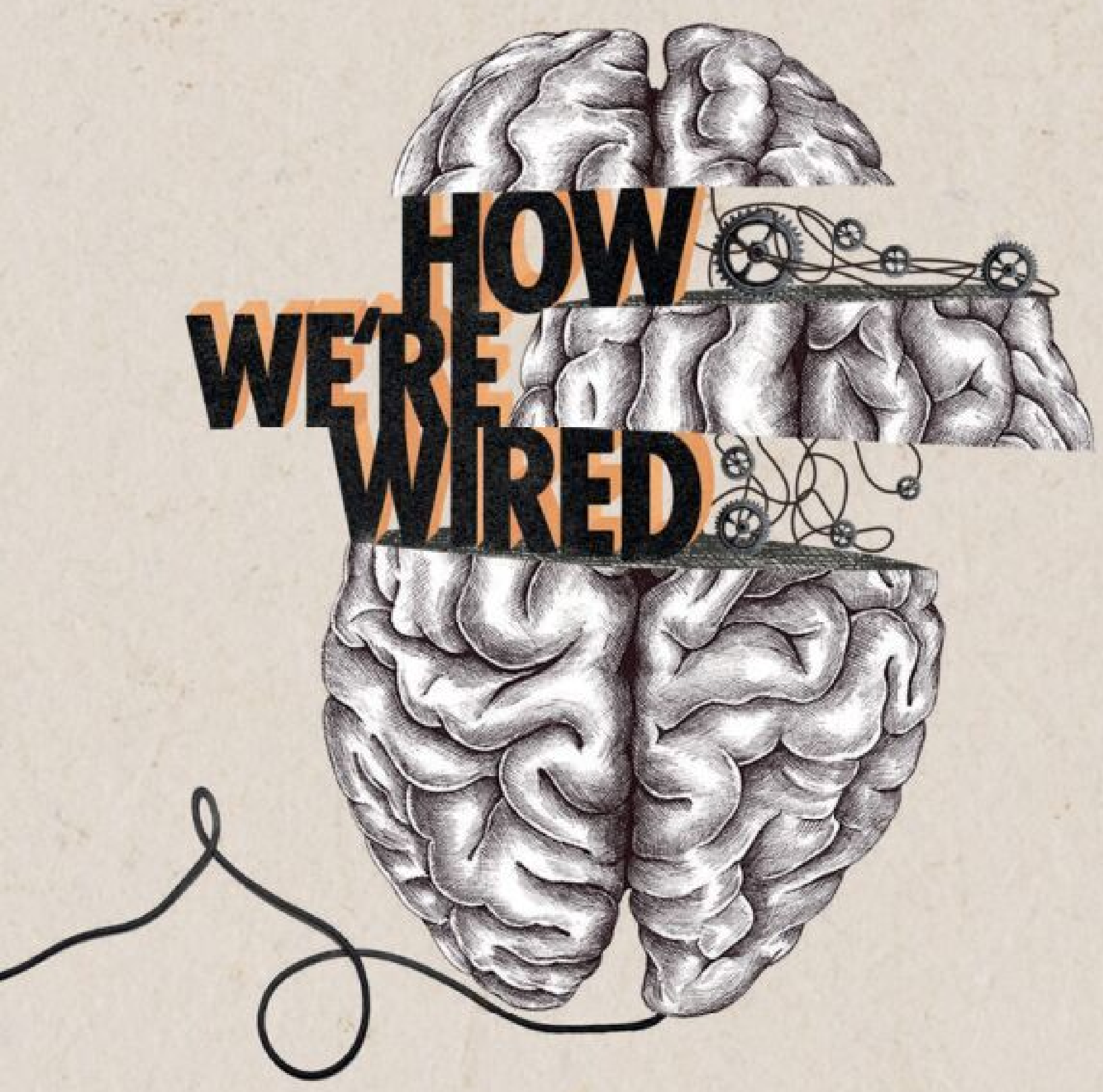

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## Virtual event

### Wonders of the Arctic: Science on top of the world

The Arctic has fascinated researchers for centuries. Join *New Scientist*'s Rowan Hooper for this free talk on the region's wildlife and how humans could refreeze ice in the Arctic circle. Glaciologist Ulyana Horodyskyj Peña will also discuss the life of a scientist in an extreme environment. On 12 January at 8pm GMT/3pm EST and on demand.

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## Academy

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**academy.newscientist.com**

## Podcast

### Weekly

Podcast editor Rowan Hooper and the team preview the coming year, looking at everything from planetary missions to the creation of synthetic human embryos. They also share their cultural picks for the year, highlighting the books and films they are most looking forward to.

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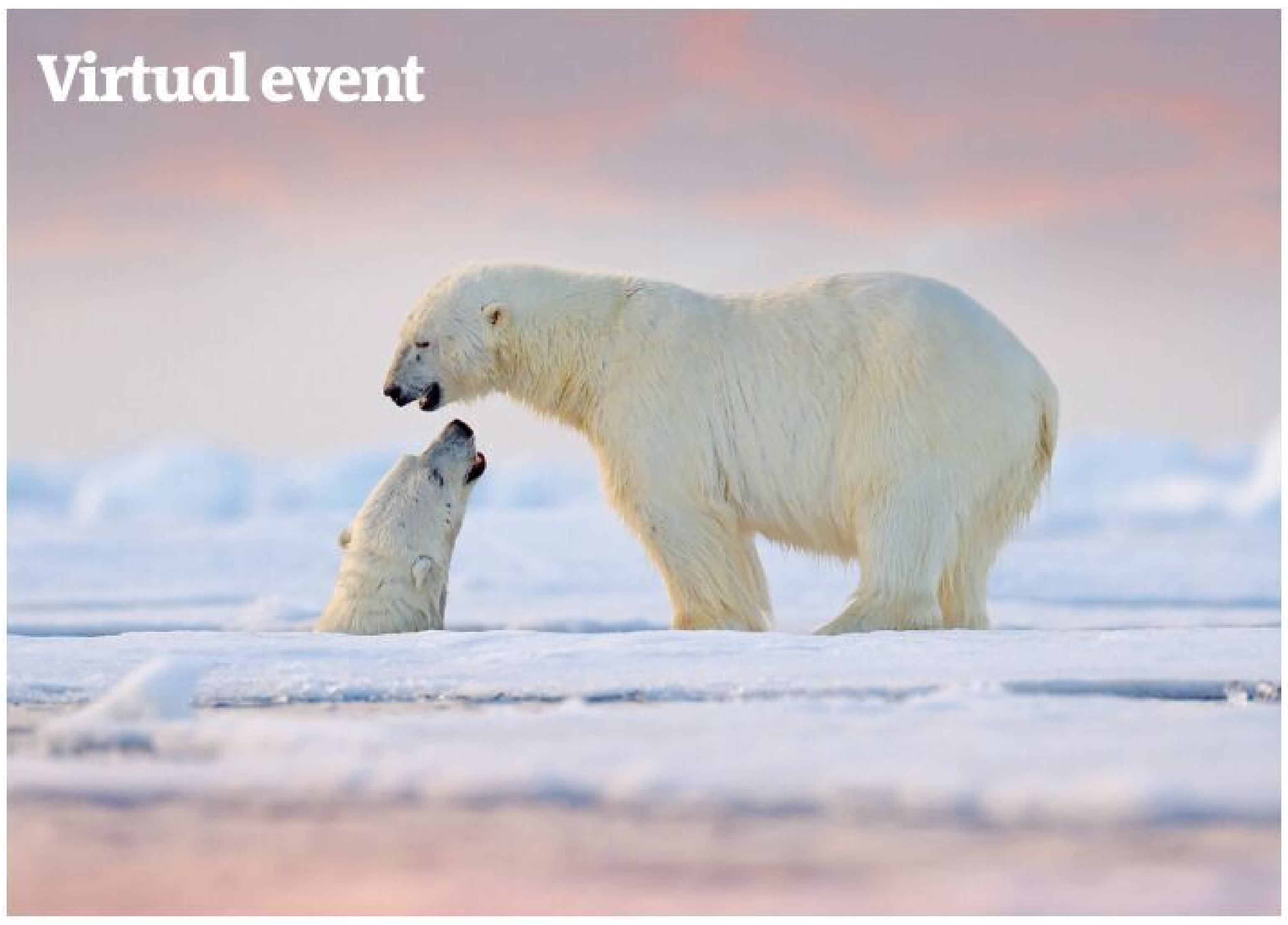

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**Icy wonderland** Could we refreeze the Arctic circle?

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**Neural network** Investigate the science of consciousness

## Video

### Perching robots

Over on our YouTube channel, you can watch a flying robot that perches on branches like a bird. The robot – which has a 1.5-metre wingspan and weighs 700 grams – has a bird-like foot with "talons". Its softer "midfoot" snaps shut when it comes into contact with a prospective perch, allowing the talons to wrap around and grip the branch.

**youtube.com/newscientist**

## Newsletter

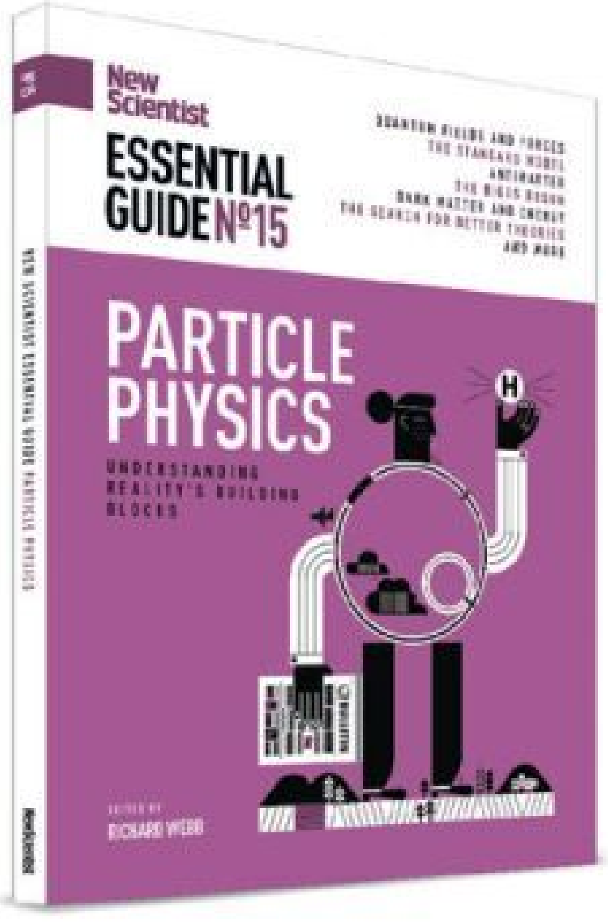
### Health Check

The UK experienced several unusual outbreaks of disease in 2022, which some pinned on an "immunity debt" tied to covid-19 restrictions, writes medical reporter Clare Wilson. Even if these were a factor, there is no evidence that coronavirus infections caused lasting damage to immune systems.

**newscientist.com/health-check**

Podcast

> "I am looking forward to eating microbial food and seeing what new cuisines can be made"



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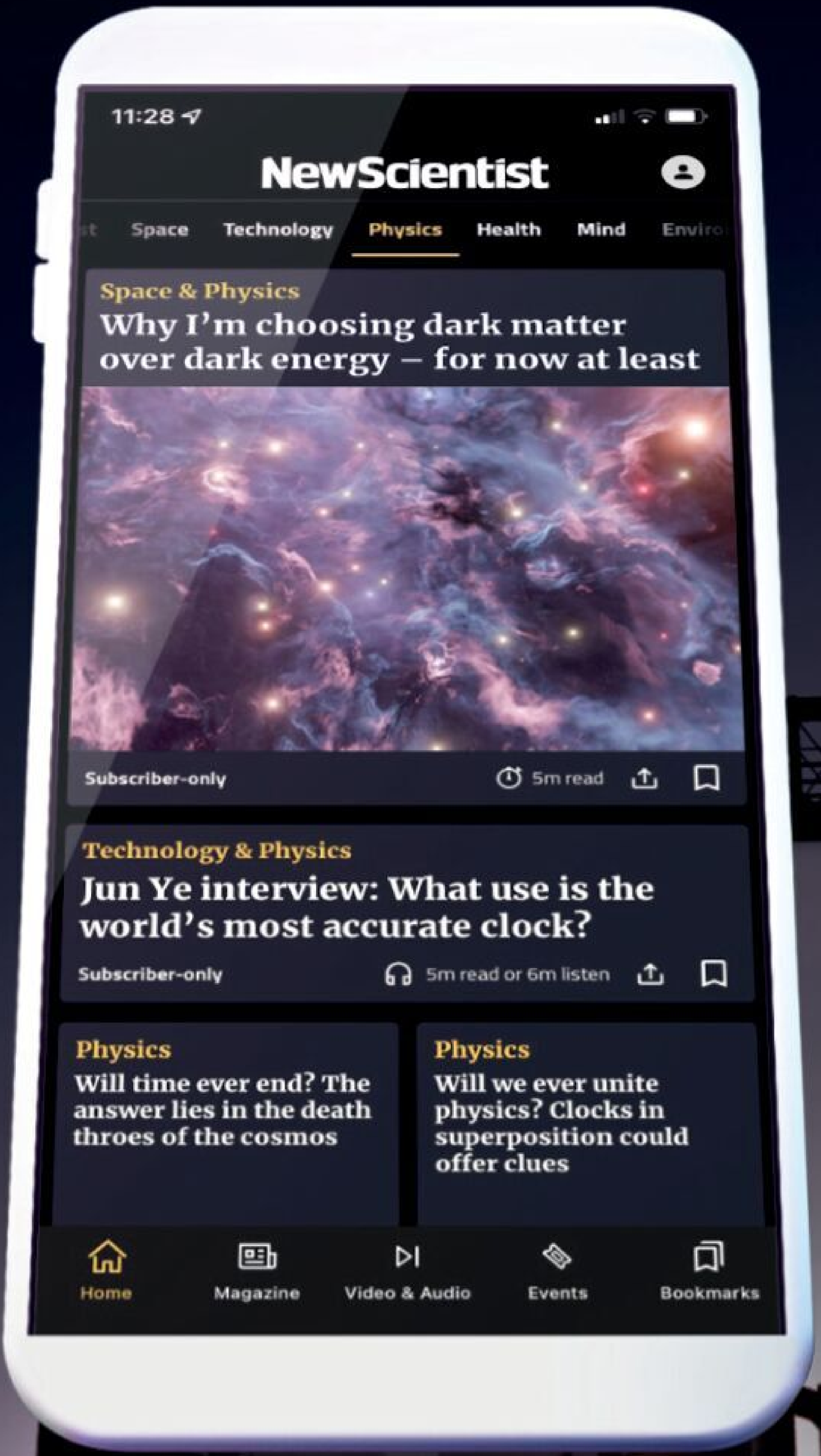

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# The invention imperative

While cutting emissions is vital to tackle the climate crisis, so too is innovation

HOW to stop our planet overheating is, of course, the key question of our time. The Intergovernmental Panel on Climate Change, a UN agency known for its sobriety and caution, has, for some time, noted that halting the current warming trajectory "requires rapid and far-reaching changes" in all aspects of society.

Some interpret that as meaning the end of capitalism. Others prefer that we innovate our way out of the problem. Certainly, we must cut our consumption of planetary resources, especially in high-income countries, and this is something that the Czech-Canadian scientist and author Vaclav Smil has argued for at length. This week, however, he leans towards innovation, highlighting key inventions that we desperately need (see "How to save ourselves", page 38).

Smil mostly limits himself to things that seem feasible in the short term, an approach also taken in related books looking at planet-saving innovations, such as *How to Spend a Trillion Dollars*, by *New Scientist*'s Rowan Hooper, and *How to Avoid a Climate Disaster*, by Bill Gates.

> **"We need to tackle the problems of the world with everything we have"**

For example, Smil identifies agriculture as an enterprise that is completely unsustainable in its current form. If we could create cereals crops with the ability to make their own fertiliser by "fixing" atmospheric nitrogen, that would allow us to cut down on the energy intensive and polluting production and use of artificial fertilisers. Similarly, improving the efficiency of photosynthesis would allow us to grow more food on less land.

These innovations would be welcome. But alone they aren't going to save us. Some 90 per cent of soya grown worldwide goes to feed livestock kept for meat, milk and eggs; cutting human consumption of animals and their products is just as vital to secure the health of our planet.

There is huge value, however, in Smil's approach, emphasising solutions and celebrating our powers of invention. We need to tackle the problems of the world with everything we have, and innovation is one of our greatest assets. ▮

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REUTERS/LINDSAY DEDARIO

**Bulldozers move snow in Buffalo, New York, on 28 December**

**Weather**

# Deadly blizzards hit US

North America has faced severe winter storms, while parts of Europe have seen record warmth for January, reports **Madeleine Cuff**

A HUGE severe winter storm blasted swathes of the US and Canada over the holiday period, with blizzards and extreme cold leaving at least 60 people dead and millions without power.

The storm, estimated to be more than 3000 kilometres wide and dubbed a "bomb cyclone", swept across North America from 23 December, hitting US states as far south as Texas as well as the Canadian provinces of Quebec and Ontario.

In Buffalo, New York, more than 120 centimetres of snow fell in 72 hours, while temperatures in Montana dropped to -39°C (-38°F). Millions faced huge disruption to their holiday travel plans, with thousands of flights cancelled and major roads blocked by snow and abandoned vehicles.

The storm was caused by Arctic winds known as the polar vortex dipping south over North America. Some scientists suspect that human-caused climate change may be fuelling this instability in polar weather systems.

The Arctic is one of the planet's fastest-warming regions, reducing the temperature difference between cold Arctic air and warmer air further south. This could be disrupting the polar vortex's flow, destabilising a high-altitude air current called the polar jet stream, causing it to push warm air into the Arctic while driving cold Arctic air south.

The extreme weather looks set to continue into the new year. As *New Scientist* went to press, large parts of the US were still under weather alerts, with the US National Weather Service (USNWS) warning that the Great Lakes region will be hit by heavy snow, freezing rain and severe thunderstorms from 3 January. It said that snowstorms and gusty winds "will result in snow-covered roads, reduced visibility, and difficult-to-impossible travel" across Nebraska, South Dakota and Minnesota.

**120cm**

**Snowfall in Buffalo, New York, over 72 hours to 26 December**

Meanwhile, California was hit by heavy rain and snow in the first few days of 2023, causing flash flooding and rock slides. It is the first of several storms forecast to strike the state over the coming days, according to the USNWS.

As North America battles freezing rain and heavy snow, in Europe, the start of the year brought record high temperatures. Belarus, the Czech Republic, Denmark, Latvia, Lithuania, the Netherlands and Poland all recorded their warmest ever January days on 1 January, according to Maximiliano Herrera, an independent climatologist who tracks extreme temperatures.

In Poland, temperatures hit 19°C (66°F) in Korbielów and Jodłownik on the first day of the year, far higher than the 1°C (34°F) average temperature for January, while the Czech Republic recorded highs of 19.6°C (67.2°F) in Javorník, compared with an average of 3°C (37°F) for this time of year. In Germany, 982 monthly temperature records were shattered in the first three days of 2023, according to Herrera.

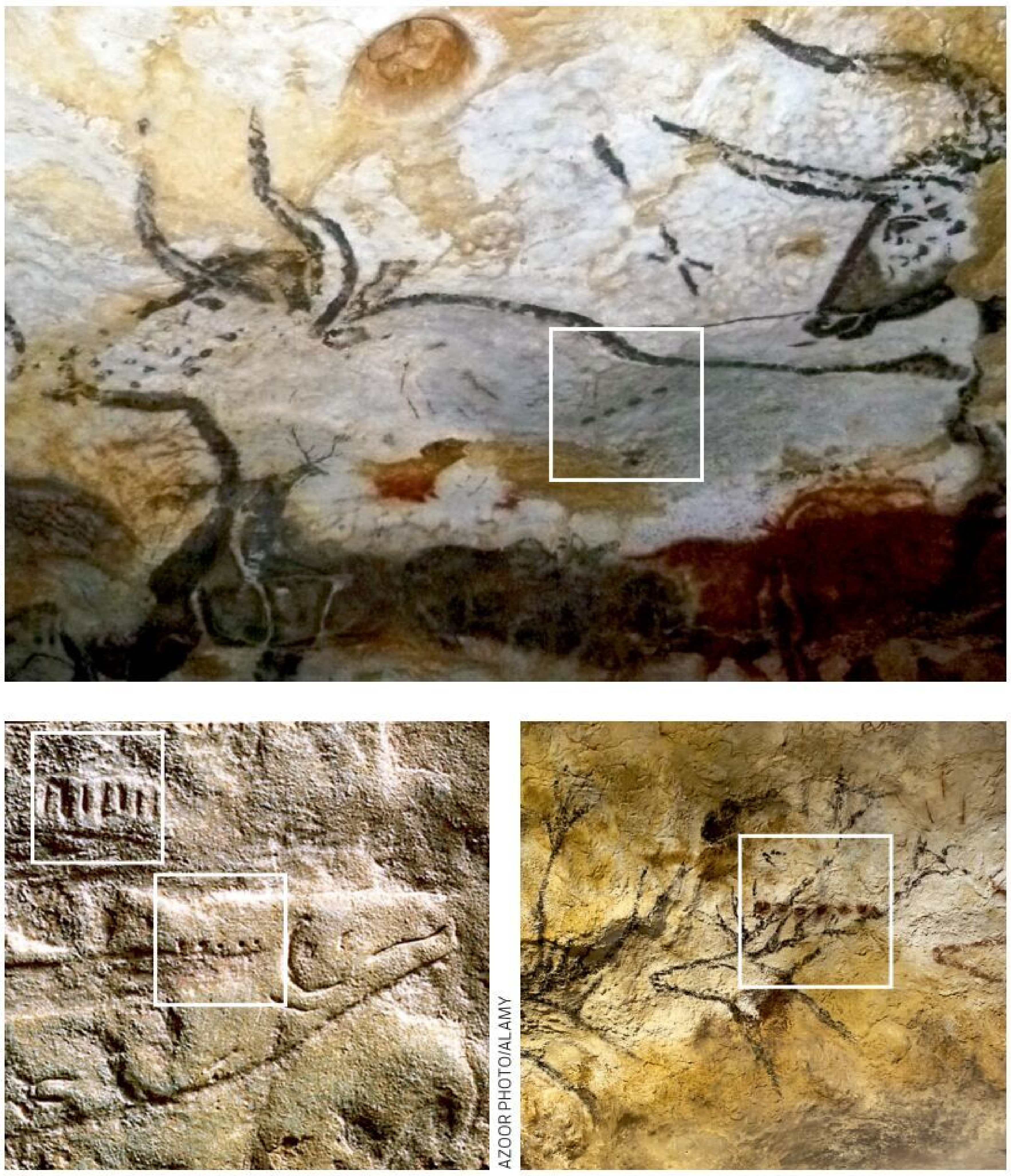
It follows a year of record warmth across Europe in 2022, which saw the UK provisionally log its hottest ever year and Europe experience the highest summer temperatures on record.

The UK's Met Office has warned that 2023 is likely to be one of Earth's warmest years on record, with the average global temperature forecast to be between 1.08°C and 1.32°C above pre-industrial levels. In a press release, Nick Dunstone at the Met Office said the forecast was affected by the expected end of a prolonged La Niña climate event, which has had a cooling effect on global average temperatures for the past three years. ▮

Anthropology

# Cave art symbols deciphered

Mysterious marks drawn on cave walls by Stone Age people may have been an early form of writing used to record the behaviour of animals, finds **Alison George**



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**Sequences of dots and lines appear on cave paintings of animals in Lascaux and Abri du Poisson, France**

STONE Age people living in Europe 20,000 years ago may have devised a simple form of writing to record the habits of the animals they hunted, according to a study of mysterious symbols on artefacts and cave walls. If confirmed, this would push back the earliest known appearance of a proto-writing system by at least 10,000 years.

At least 400 caves in Europe, such as Lascaux and Chauvet in France and Altamira in Spain, have art on the walls drawn by *Homo sapiens* groups from around 42,000 years ago onwards. As well as drawings of bison, deer and horses, there are many graphic symbols, such as lines, crosses, dots and asterisks, whose meanings have long been debated.

One common motif is a picture of an animal with a series of lines and dots on or next to it, and such symbols are also found on numerous portable objects, such as carved bones.

Ben Bacon, an independent researcher based in London with an interest in early writing, decided to investigate these images. He compiled a database of animal images and their associated graphic symbols that had been depicted on cave walls or on portable artefacts between 20,000 and 10,000 years ago – the period when the majority of these motifs were created – and looked for patterns in the data, first on spreadsheets, then using statistical tools. "If you can find patterns, then you can start to work on the meaning," he says.

> "This is exactly the sort of thing I'd expect Palaeolithic hunter-gatherers to record"

Bacon noticed that certain patterns were particularly common. He found 606 depictions of animals together with a sequence of dots or lines. Horses, for example, typically had three marks, whereas mammoths had five. He also found 256 instances of these marks alongside a "Y" symbol, which was typically in the second position of the sequence.

To work out what these patterns might mean, he enlisted a team including archaeologist Paul Pettitt at Durham University, UK, and Tony Freeth at University College London, who discovered key functions of the ancient Greek Antikythera mechanism as an astronomical calculator.

One avenue they investigated was how the patterns of symbols matched data on the reproductive habits of the species depicted – which included deer, wild cattle called aurochs, mammoths and horses – such as the month when they mated and gave birth.

## Hunting calendar

The analysis indicates that the marks were a lunar calendar that began at the start of spring, with each line or dot denoting a month. The number of marks in a sequence shows how many months after the beginning of spring a particular animal's mating season began, while the position of the Y mark denotes the month when they gave birth (*Cambridge Archaeological Journal,* DOI: 10.1017/S0959774322000415).

"This is exactly the sort of thing I'd expect Palaeolithic hunter-gatherers to record," says Pettitt. "If anything was worth recording outside of memory, it would be animals, particularly the times of the year when those prey animals, critical for survival, would be aggregated together and preoccupied with mating and birthing. It makes absolute sense."

This calendar system seems to have been remarkably stable, in use for a period of at least 10,000 years and in different geographical regions, such as what is now Spain, France and central Europe, enabling the transmission of information over multiple generations.

"It's a very interesting theory," says palaeoanthropologist Genevieve von Petzinger. The next step would be to test this idea on a bigger database of symbol sequences, she says.

Karenleigh Overmann at the University of Colorado in Colorado Springs thinks this study is a step in the right direction, but isn't convinced that the graphic signs are a calendar. It is harder than you might think to distinguish what exactly constitutes a Y sign or a line in cave art that is tens of thousands of years old, she says. "I find the definition of what constitutes one of these repeated symbols a bit problematic."

However, if this calendar system is confirmed by further analysis, it means we may need to rethink our understanding of the origins of writing. The first full writing system, cuneiform, appeared around 3500 BC, and it was preceded by proto-writing that has roots going back to clay counting tokens that appeared around 10,000 years ago. ▮

Biology

# New way to sneak drugs into brain has promise for hard-to-treat illnesses

Michael Le Page

THE blood-brain barrier can stop large and potentially therapeutic molecules from reaching the brain, making conditions such as Alzheimer's, Parkinson's and brain tumours hard to medicate. Now, a study in mice led by Wenchao Gu at Cornell University in New York suggests that using one of the body's own systems could bypass this hurdle.

Many drugs are essentially proteins, which can be difficult and expensive to make. Giving people mRNAs, which provide the genetic code for making proteins in their bodies, should be much cheaper. Such mRNAs have already been used in covid-19 vaccines.

However, getting enough mRNAs into the right cells remains a challenge, especially in the brain.

A problem with many existing ways to do this, such as using benign viruses to get therapeutic molecules into various cell types, is that the immune system targets the delivery vehicle, so people can't be given repeated doses.

Many groups have therefore been trying to take advantage of a natural transport system called extracellular vesicles. These are little "bags" of molecules that bud off from cells and fuse with other cells, delivering their contents.

In 2018, Jason Shepherd at the University of Utah and his colleagues showed that in the nerve cells of mammals, mRNAs with sequences that include a specific bit of extra genetic code get packed into virus-like particles, called Arc particles. These are then released in extracellular vesicles, which transfer this mRNA to other neurons.

Gu and her colleagues have now shown that any cell type can produce extracellular vesicles containing specific mRNAs if the genes for the Arc proteins and the extra code for the mRNAs are added to the cells.

To target the brain, they used immune cells called leucocytes to produce the vesicles. Leucocytes have surface molecules that enable them to get through the blood-brain barrier, but only if inflammation is present. The vesicles that bud off leucocytes also have these features and can therefore pass through the barrier.

"This method could treat the likes of Parkinson's, Alzheimer's and brain cancers"

When these extracellular vesicles were injected into the blood of mice, the animals' neurons produced proteins encoded by packaged mRNAs, providing there was some inflammation in the blood-brain barrier (bioRxiv, doi.org/10/jrq2).

The need for inflammation means this approach could deliver drugs for some illnesses. "Many neurodegenerative conditions have a degree of blood-brain barrier inflammation," says Francesco Muntoni at the UCL Great Ormond Street Institute of Child Health in London. It also means the therapeutic protein encoded by the mRNA would be concentrated in the parts of the brain that need it, says Gu.

This method could treat the likes of Parkinson's, Alzheimer's and brain cancers, says team member Shaoyi Jiang at Cornell University. Collaboration with other groups at Cornell that work in these areas is under way. "We are getting lots of good results," says Jiang. "But we are not ready to discuss them yet." ▮

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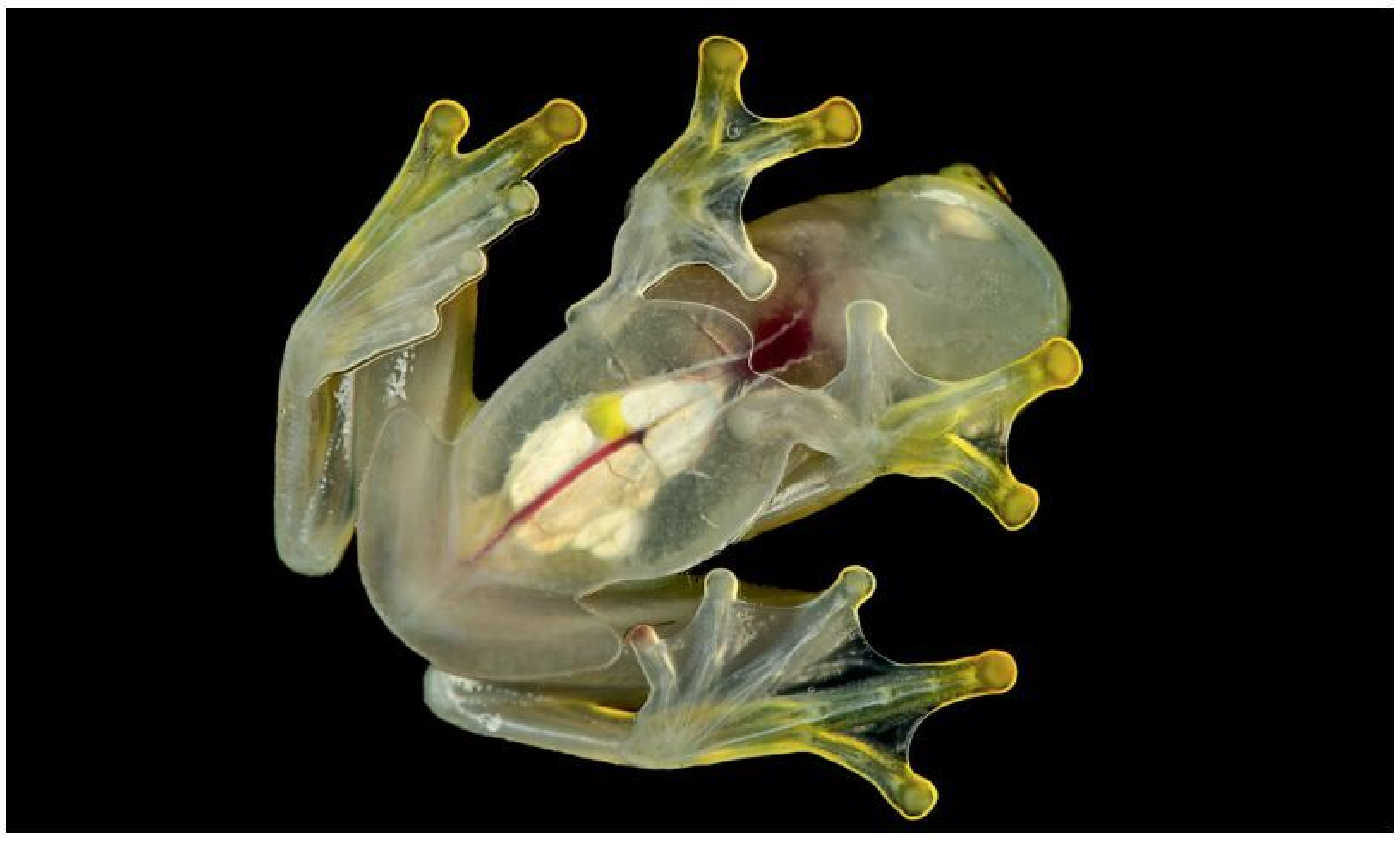
Physiology

# Frogs 'hide' their blood to become more see-through

**GLASS frogs can boost their transparency by storing most of their blood in their liver while they sleep.**

**Fleischmann's glass frogs (*Hyalinobatrachium fleischmanni*) spend their days sleeping on bright green leaves. Being semi-transparent helps them avoid detection by predators, but it is a challenging task, as most animals need to continuously pump red blood cells throughout their body to deliver oxygen to their tissues.**

**"If it wasn't for that green skin on their back, you would probably be able to read a newspaper through them," says Jesse Delia at the American Museum of Natural History in New York.**



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The transparent belly of a male glass frog found in Chocó Forest in Ecuador

**Delia and his colleagues noticed that the animals appeared much more see-through while sleeping compared with when they were awake, so they measured the frogs' opacity by shining different wavelengths of light through them while they were active and while they were resting. The researchers found that the frogs became up to 61 per cent more transparent when asleep.**

**When they traced the movement of blood in the animals in real time using photoacoustic imaging, Delia and his team discovered that glass frogs can "hide" around 89 per cent of their red blood cells in their liver while they slumber (*Science*, doi.org/grjd22).**

**In most vertebrates, packing red blood cells together leads to clotting, but these amphibians don't appear to experience negative health consequences from storing blood in their liver. Delia says the team isn't sure yet how glass frogs manage to evade coagulation, but hopes the work can advance the treatment of blood clots in humans.** ▮

Corryn Wetzel

**Analysis** Environment

# Will new biodiversity targets revitalise the natural world?

The Kunming-Montreal pact sets bold ambitions for protecting wildlife, but a dispute about finance risks undermining it, says **Madeleine Cuff**

A GLOBAL pact agreed on by almost 200 countries on 19 December has been hailed as a groundbreaking framework to transform humanity's relationship with the natural world.

UN Secretary-General Antonio Guterres called the deal, which sets an overall ambition to "halt and reverse biodiversity loss" by 2030, a "peace pact with nature".

But the last time nations came together to set targets to halt biodiversity loss and restore nature, in 2010, it was a failure. Not a single one of the 20 Aichi Targets was fully achieved, and scientists warn the rate of species extinction and biodiversity collapse has accelerated in the past decade. Why should this time be any different?

The global attitude to biodiversity loss has changed, says Tony Juniper at Natural England, a UK government agency. "In 2010, when those targets were agreed, I believe that many people in boardrooms and in national government [felt that] the loss of nature was regrettable but it was the inevitable price of progress," he told reporters at the COP15 biodiversity conference in Montreal, Canada. "Whereas today we have a much stronger understanding that this is not just about endangered species and declining animals and plants. This is about the future of the economy."

That urgency should spur bolder action this time, he argues: "The penny does seem to have dropped."

Negotiators drafting the Kunming-Montreal pact set out to ensure countries could be held to account, by creating precise, numerical targets and a clear mechanism for nations to review and improve progress in the coming years.

On this, only partial success was achieved. A programme of regular annual reports and global stocktakes is planned to make sure the agreement stays on track. But a "ratchet" mechanism, meant to compel countries to improve their ambition if the world is falling short against the treaty, was weakened to become voluntary.

Overall, the pact is better designed than the Aichi goals, says Pierre du Plessis, a negotiator for Namibia.

**30%**

**Fraction of Earth's land and sea the deal aims to protect by 2030**

"I think we have learned [from Aichi], and I think the fact that it will be a much more ongoing process of monitoring and reporting will probably help," he says. "I think the chances are that it will be better than Aichi."

Some of the goals, such as the target to protect 30 per cent of land and oceans by 2030, are clear and measurable. But goals on the so-called drivers of biodiversity loss, such as reducing overconsumption and tackling pollution, are much vaguer, says Bernadette Fischler Hooper at WWF UK.

Without clear goals and a forceful mechanism to compel countries to do better, the role of campaigners to hold governments to account becomes more important, says Fischler Hooper. "All eyes will be on the parties, and we will definitely push them to do it," she says.

Craig Bennett, CEO of UK nature charity The Wildlife Trusts, says the pact gives charities like his fresh ammunition to level at laggard governments. Already he is calling on the UK government to redraft the environment targets it published on 16 December. These ambitions fall short against the Kunming-Montreal agreement, he says, pointing to the absence of a target to increase protected areas or reduce harm from pesticides. "[The targets] need to be looked at again to make sure they are in line with what has been agreed in Montreal," he says.

Ultimately it will be up to governments to decide if they will live up to what has been promised in Montreal. That may have been made more difficult by the final moments of the summit, which saw the Chinese presidency swiftly gavel the pact through despite objections from the Democratic Republic of the Congo (DRC). Negotiators from the DRC objected on the basis that the deal doesn't set up a new, dedicated fund for financing biodiversity action.

**Delegates applaud as the deal is adopted on 19 December in Montreal**

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XINHUA/SHUTTERSTOCK

In the immediate aftermath, parties reacted furiously to the rushed way the text was adopted, with Uganda's negotiator claiming there had been a "coup d'état" of the summit. Ève Bazaiba, the DRC environment minister, told *The Guardian* her country didn't recognise the agreement and threatened a legal challenge.

After urgent negotiations and diplomatic phone calls to smooth over the disagreement, the DRC eventually dropped its formal objections to the agreement in the summit's final plenary later that day.

But the roots of the dispute remain. Many African nations, including the DRC, left Montreal disappointed the pact won't deliver a new, dedicated fund for biodiversity. The existing Global Environment Facility (GEF) is widely criticised for being bureaucratic and difficult to access. A new "trust fund" to deliver the deal is promised, but as this will be established under the GEF, there are fears the same issues will persist.

The new GEF fund also needs filling. Richer countries have promised to treble their contributions to $30 billion a year by 2030, but this is still a "paltry" amount compared with the estimated $700 billion a year needed to fulfil the deal, says Abigail Entwistle at Fauna & Flora International. "The biggest hurdle to effective delivery will, as always, be finance, and we see a noted lack of ambition in this regard," she says. A lot rests on planned reforms of multilateral institutions and increasing flows of private finance into nature.

Without adequate funding, poorer yet biodiverse nations may struggle to implement the promises of the treaty – leaving some of the planet's wildest places at risk. ▮

Biology

# Parasitic DNA may shorten our lives without even damaging genes

Michael Le Page

GENETIC "parasites" known as retrotransposons become more active in all kinds of animals as they age, and this increased activity shortens lifespans. Now, an animal study has shown that this ageing effect isn't due to mutations to the genome as previously thought, but could be a result of the parasite activity triggering an immune response.

Understanding exactly how these chunks of parasitic DNA shorten lifespans could lead to ways to extend human lives. "But this is very far down the road," says Blair Schneider at the Albert Einstein College of Medicine in New York, who led the research.

The genomes of all animals are infested with retrotransposons, which are bits of DNA that can copy and paste themselves into other parts of the genome. This is dangerous as it can disrupt key genes and even trigger cancer. So cells have mechanisms for suppressing the activity of retrotransposons – that is, for stopping their DNA being transcribed into RNA, the first step in the copying process.

MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY

**Retrotransposons are bits of DNA that can infest our genomes**

As animals age, however, these mechanisms start to fail and retrotransposons become more active. Numerous studies have shown that this increased retrotransposon activity is linked with many age-related diseases, from rheumatoid arthritis to Alzheimer's, and that suppressing this activity can extend the lifespan of animals such as mice.

The obvious explanation is that as retrotransposons become active, they generate lots of harmful mutations by pasting copies of themselves into the genome. To find out how many mutations accumulate, Schneider and her colleagues sequenced the genomes of individual cells from young and old fruit flies (*Drosophila melanogaster*) so they could directly measure the number of new insertions. Their study is the first to look at this at the level of individual cells (bioRxiv, doi.org/jqxp).

To their surprise, there was no significant increase in retrotransposon insertions in the cells from old flies – "which we didn't believe to start with", says team member Julie Secombe, also at the Albert Einstein College.

The team only looked at a few tissue types because of the difficulty in analysing single cells. But Schneider says she is aware of another team finding similar results in human cells, in as-yet unpublished work.

Despite the lack of new insertions, the results add to the evidence that retrotransposon activity reduces lifespan. When the team suppressed the activity of just one retrotransposon, it extended the lifespan of the flies by nearly 10 per cent.

"Cells may mistake retrotransposon activity for a viral infection and trigger immune responses"

So what is going on? "The short answer is, we are not really sure," says Schneider. But the team did find an increase in the activity of genes linked to the immune system. What may be happening is that cells mistake retrotransposon activity for a viral infection and trigger immune responses that lead to persistent inflammation. This type of inflammation is thought to be one of the causes of ageing.

"It's a very interesting study," says Vera Gorbunova at the Rochester Aging Research Center in New York. "It supports the concept that transposons affect ageing mostly by inducing inflammation rather than by inducing mutations." ▮

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Wildlife

## Canada geese return twice as quickly if you shoo them away

**CANADA geese can be a nuisance, but harassing them to leave an area may backfire.**

**These birds, which often take up residence in densely populated areas of North America and northern Europe, sometimes attack people during nesting season, leave droppings on playground equipment and, most seriously, pose a risk to air traffic at airports.**

**Ryan Askren, then at the University of Illinois, and his colleagues tested whether harassing geese was an effective way to make them leave the area.**

**He fitted geese in Marquette Park near Midway Airport in Chicago with GPS trackers and activity monitors to record their behaviour, then he and his colleagues repeatedly chased them out of the park, by walking or driving towards them clacking wooden boards together.**

**The idea behind harassment is to force the geese to expend energy to escape a threatening situation, so that they decide the risk of staying in a particular location outweighs the benefits they get from being there, in the form of food or rest. But while the geese quickly left when approached, they soon came back. In fact, the geese returned to the park twice as quickly on days when they were harassed, compared with days when they left of their own accord (*Wildlife Society Bulletin*, doi.org/grb93n). "They seemed to perceive that we weren't a real threat, just a mild annoyance," says Askren.**

RYAN ASKREN

Ryan Askren and a Canada goose fitted with a tracking collar

**Lynsey White, director of humane wildlife conflict resolution at the Humane Society of the United States, isn't surprised that the harassment didn't work, given the simple technique used. "It's fairly well established that the most effective techniques for aversively conditioning Canada geese are with specially trained goose dogs or with human-operated lasers," she says.** ▮

**Brian Owens**

**Physics**

# Messages from the other side

It may be possible to send a signal back through a wormhole before it collapses

**Leah Crane**

WORMHOLES – bridges that create a shortcut between two distant locations in space-time – are still hypothetical, but models suggest they would be fragile and liable to implode if anything fell in. Now, simulations suggest a pulse of light may be able to outrace that collapse.

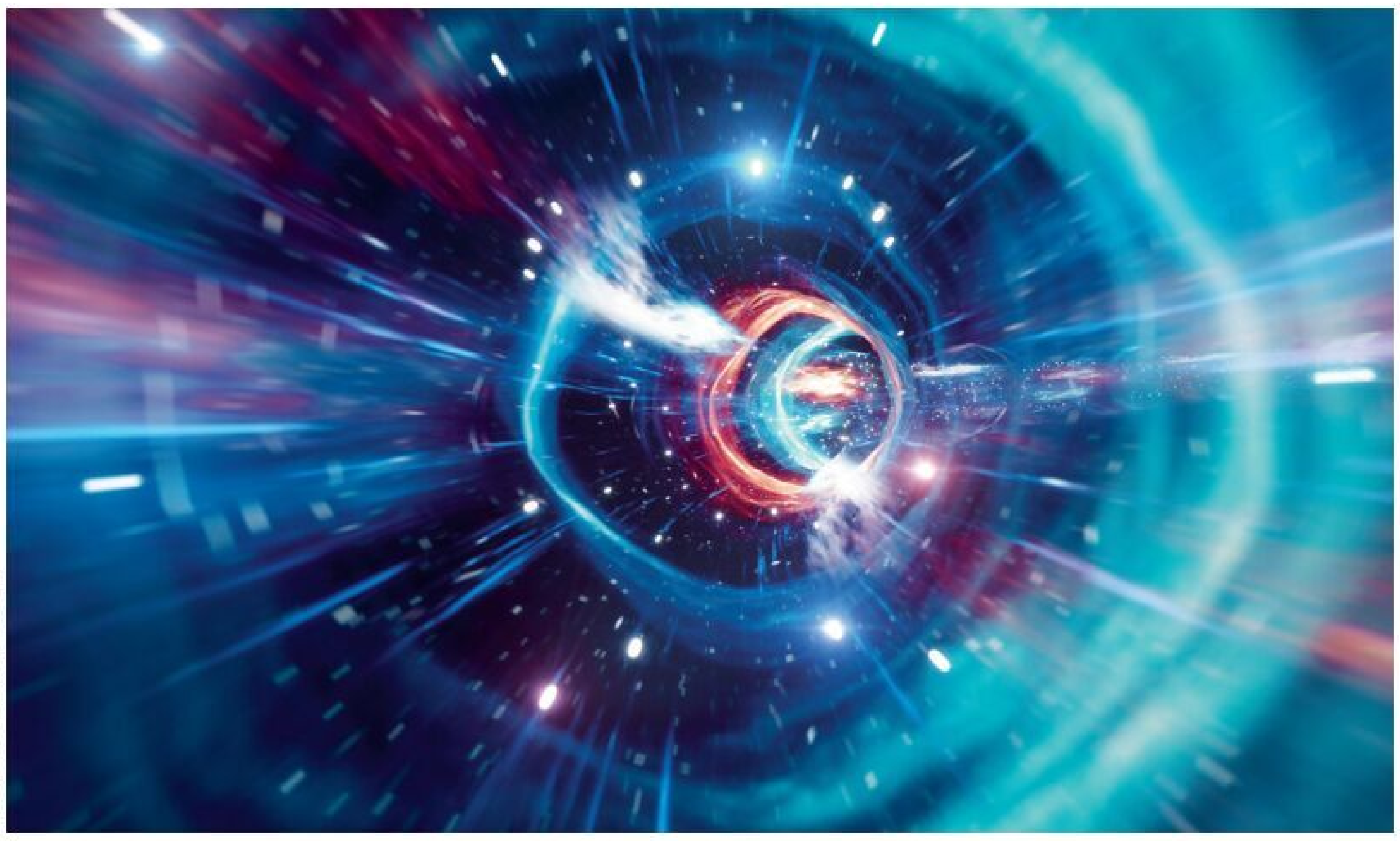
Ben Kain at the College of the Holy Cross in Massachusetts and two of his students simulated a traversable wormhole to examine what would happen when matter entered it. They found that normal matter would make the wormhole rapidly collapse, but not so fast that you couldn't, in theory, send a message home first.

The type of wormhole they simulated is held open by an exotic type of theoretical matter called ghost matter, which has negative energy. There is some evidence that very small amounts of negative energy can be created through quantum effects, but the idea that there could ever be enough to make a wormhole is still extremely speculative.

"We simply put a negative sign in front of the energy. From a physical standpoint, this may be completely ridiculous; such matter may have no relationship with reality," says Kain. "Wormholes are hypothetical to begin with, so using hypothetical matter maybe isn't the biggest stretch." The negative energy is required in the simulations to make the wormhole traversable.

"This is at the boundary of what is science and what is not," says Francisco Guzmán at the Michoacan University of Saint Nicholas of Hidalgo in Mexico. Nevertheless, simulating speculative objects could help us understand extreme space-time phenomena that are more likely to exist, he says.

**Wormholes create a shortcut between two locations in space-time**



ROST9/SHUTTERSTOCK

This particular kind of wormhole wouldn't look like more traditional ones with black holes at either end. "It would look just like the space around it," says Kain. But add in a little regular matter and the bridge would begin to narrow and then close, and the entrances at either end would collapse and become two distinct black holes (*Physical Review D*, doi.org/jq4n).

While this process would be fast, it wouldn't be instantaneous. "We don't see a way that you could return after going through it, but you could get a signal back to your friends," says Kain. This means that one could hypothetically send a probe through this kind of wormhole to learn something about the other side – although in the simulations, not all of the matter made it through, so it is unclear whether the probe would make it in one piece.

Unfortunately, the fact that this type of wormhole would collapse when any matter fell in also means that it would be extraordinarily difficult to maintain one for any reasonable amount of time.

"Sure, once one of these wormholes forms, a signal could go through, but there's still a question of how you could form one in the first place," says Olivier Sarbach, also at the Michoacan University of Saint Nicholas of Hidalgo. ▮

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**Technology**

## Golf robot navigates to a ball and sinks a putt by itself

A ROBOT called Golfi is the first to be able to autonomously spot and travel to a golf ball anywhere on a green and sink a putt.

Golf-playing robots have been developed before, but they have needed humans to set them up in front of a ball and program them to make the correct swing. The most famous is LDRIC, a robot that hit a lengthy hole-in-one at Arizona's TPC Scottsdale golf course in 2016.

In contrast, Golfi, engineered by Annika Junker at Paderborn University in Germany and her colleagues, can find golf balls and wheel itself into place thanks to input from a 3D camera that looks down on a green from above.

The camera scans the green and an algorithm then approximates the surface before simulating 3000 golf swings towards the hole from random points, taking into account factors such as the mass and initial speed of the ball once hit and the green's friction, which are described by physics-based equations.

This trains a neural network to work out how hard and from what angle the robot should hit any ball.

"It's like how professional golfers often practise their strokes on a green the day before they play," says Junker, who presented the robot at the IEEE International Conference on Robotic Computing in Naples, Italy, in December.

After this, Golfi and a ball can be placed anywhere on the green and the robot will navigate to the ball and try to hit it into the hole.

**"It's like how professional golfers often practise their strokes on a green the day before they play"**

Golfi was able to sink more than 60 per cent of putts on a flat, 2-square-metre, indoor green. The robot isn't suited to outdoor greens because it requires a power connection and the 3D camera to be mounted above the green.

However, the idea of Golfi isn't to win golf tournaments. It is meant to show how robotic applications can be simplified by combining physics-based models with machine learning, says team member Niklas Fittkau, also at Paderborn University. ▮

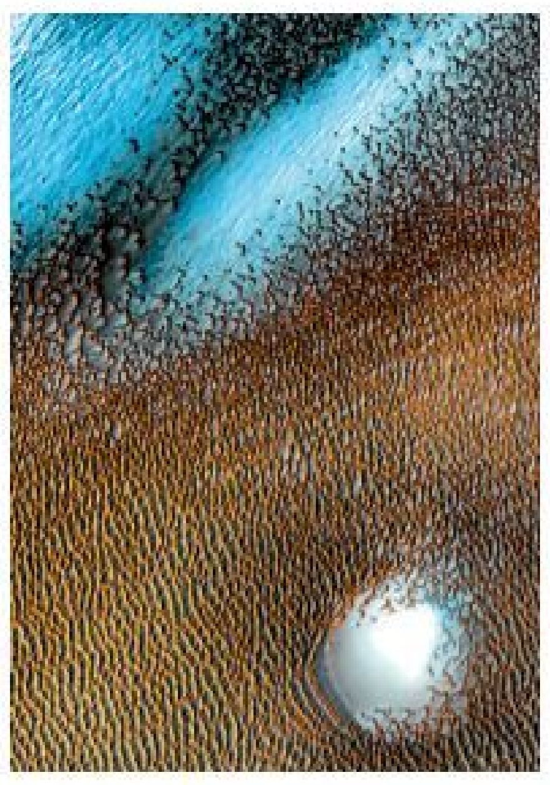
**Alice Klein**

**Space**

# Mars has enough wind to power bases all year round

**Christa Lesté-Lasserre**

**WIND turbines on Mars could theoretically provide enough energy for scientists to safely explore the poles of the planet during crewed missions.**



Dunes sculpted by the wind surrounding the northern polar cap on Mars

NASA/JPL-CALTECH/ASU

**Solar energy might be sufficient for investigating Mars near the equator, but to live nearer the poles all year round, other power sources are needed. Because of the planet's thinner atmosphere, there have been doubts about the potential of wind.**

**Victoria Hartwick at the NASA Ames Research Center in Mountain View, California, and her colleagues adapted a global climate model that was originally designed for Earth to simulate the wind speeds across Mars. For each unit area on Mars, the researchers calculated the theoretical power returns from four commercial turbines of various sizes currently used on Earth (*Nature Astronomy*, doi.org/grhvv7).**

**In combination with solar power, well-placed wind turbines could supply enough energy for a group of six people to live and work on Mars all year round, without the radiation risks associated with nuclear energy, says Hartwick.**

**"It's really exciting that by combining potential wind power with other sources of energy, we open up large parts of the planet to exploration and to these really scientifically interesting zones that the [scientific] community may have previously discredited because of energy requirements," she says. ▮**

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**Biology**

# Living in trees may have led to the evolution of consonants

**Richard Kemeny**

OUR complex speech may have originated from life in the trees. The first analysis of the evolution of consonants suggests that their roots may be linked to an arboreal lifestyle, hinting that our ancestors spent more time in trees than currently thought.

All human languages use a mix of vowels and consonants to transfer information. Most primates communicate almost exclusively using vowel-like calls, but non-human great apes produce consonant-like sounds to varying degrees.

This raises the question of where consonants came from, says Adriano Lameira at the University of Warwick in the UK. To find out, Lameira combed through existing literature to see how common consonants are among the great apes and if this could shed light on their evolutionary origin.

He found that wild orangutans, which spend most of their time in the forest canopy, produce a greater number and variety of consonant sounds than wild gorillas, chimpanzees and bonobos, which live on the ground (*Trends in Cognitive Sciences*, doi.org/jq2v). All orangutans produce these sounds, but in other great apes they aren't universal.

**Orangutans make a wide range of consonant-like sounds**

MEDIA DRUM WORLD/ALAMY

"Orangutans have this rich repertoire of kiss sounds, scrapes and clicks and raspberries and smacks," says Lameira. They typically use these sounds while building nests or communicating with their young, or as alarm calls.

Lameira thinks that living in the trees may explain why orangutans have evolved this broad vocal repertoire. Great apes are adept at extracting hidden or protected foods, like nuts, a skill that often requires the use of tools. While foraging up in the canopy, however, orangutans must always use at least one arm to maintain stability. They have therefore developed more complex control of their lips, tongue and jaws, allowing them to use their mouths as a "fifth limb" – orangutans can peel an orange just with their lips, for example.

As a side effect, this advanced motor skill gave orangutans an increased ability to make consonant-like sounds, argues Lameira. This could mean that our early ancestors developed consonant sounds while hanging around in the trees, too.

"There's a growing sense that our dependency on trees was much larger and deeper than we think," says Lameira, which goes against the idea that humans started walking upright as they moved into the savannah.

**"There's a growing sense that our dependency on trees was much deeper than we think"**

The link between feeding and vocal communication doesn't apply to smaller tree-dwelling primates such as monkeys, says Lameira, because their size and their tails make them more stable on branches and they forage differently.

"The arboreal origin of consonants is an interesting hypothesis worth testing," says Chris Petkov at Newcastle University, UK, though he questions some aspects. As humans aren't tree-dwelling, there must be other reasons why consonants persisted, such as growing social networks driving an expansion of call types. These hypotheses could be tested by characterising consonant-like vocalisations more systematically across species, he says.

"Given that we do not know what led to the evolution of consonants, I think testing this hypothesis can potentially provide some insights," says Serge Wich at Liverpool John Moores University in the UK. "Of course, we have to remain very cautious that even if there would be a relationship, this does not mean causality, as there could be other factors involved." ▮

Energy

# Turning Iceland green

The small nation contributes little to climate change, but is developing a suite of technologies that could help other countries cut their carbon emissions, reports **Michael Le Page**

INSIDE a small, geodesic dome near Iceland's Hellisheiði geothermal power station, water full of carbon dioxide is being pumped hundreds of metres down into the porous basalt. At least, I am assured it is: the water is so clear that the pipe looks empty when I peer through a viewing window at it. The $CO_2$ will react with metals in the rock and turn into carbonates, locking it away safely for millennia.

For Iceland, this project is a way to help achieve its aim of becoming carbon neutral by 2040. Given that the nation is responsible for just 0.01 per cent of global carbon emissions, this isn't going to make much difference by itself. But technologies like this that are being developed and tested in Iceland are helping many other countries go green too.

Iceland has already gone further towards becoming renewable than just about any other nation. It started developing geothermal power in the 1930s, with the first project providing hot water for a swimming pool, school and hospital in Reykjavik.

When an energy crisis hit in the 1970s, the Icelandic government accelerated the development of geothermal and hydropower. Today, its electricity comes almost entirely from renewable sources, with around 70 per cent from hydropower and 30 per cent from geothermal plants. This means Iceland is one of the few countries to green its electricity supply.

What's more, nearly 90 per cent of its heating is provided by hot water from geothermal plants, with most of the remainder coming from electricity and just a few isolated buildings still using oil boilers. This puts Iceland well ahead of other nations: in the European Union, renewables provide just 23 per cent of heating and cooling energy on average.

ARTERRA/UNIVERSAL IMAGES GROUP VIA GETTY IMAGES

**The Svartsengi geothermal power station in Iceland**

With the current energy crisis, the benefits of going renewable are greater than ever. While soaring energy costs in many places are hitting people and businesses hard, in Iceland, they remain low. "We have 20-year price stability," says Dagný Jónsdóttir at geothermal company HS Orka. This cheap, green power has attracted businesses such as data centres to Iceland, and that is only increasing, she says. "We are getting a lot more interest from Europe because of the crazy electricity prices."

Yet Iceland still has a long way to go to become carbon neutral. In fact, if you count emissions from land use, by some estimates, Iceland has the highest per capita emissions in Europe, at 41 tonnes of $CO_2$ or equivalent per year.

However, this doesn't reflect the carbon footprints of individuals. More than half of this is emissions triggered by the draining of wetlands for farmland from the 1950s, with carbon still being released as the land dries. To address this, the Icelandic government plans to reflood wetlands and step up reforestation.

Even excluding land use, Iceland's per capita emissions are higher than most other European countries. Yet much of this is to do with heavy industries, such as aluminium smelting. While this smelting uses renewable electricity, it still relies on carbon electrodes that burn up during the process, releasing large amounts of $CO_2$. Several companies, including an Icelandic one called Arctus, are developing alternative approaches that get rid of the carbon electrodes and the carbon emissions.

In general, however, by using renewable electricity to run data centres or produce products that are then sold abroad, Iceland is effectively exporting its green economy to the rest of the world. "The export of energy in Iceland is through products," says Jónsdóttir.

"All parties in Iceland are behind the effort to go green, thanks to the energy crisis"

That said, there is debate in Iceland over the extent to which it should expand energy production to support industries. There is plenty of power left to tap, but there is a catch. "The best geothermal sites are in the most picturesque sites," says Bjarni Richter at Iceland GeoSurvey, a state-owned company.

## Green transport

After industry, next on the list of emissions sources is transport. In Iceland, the greening of transport is referred to as the third energy transition, after electricity and heating. For cars, this is relatively straightforward. Iceland is second in the world behind Norway in electric cars per capita, with sales of petrol and diesel cars due to end in 2030.

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Even domestic flights could go green. Icelandair began testing a small electric plane in 2022 and is looking into buying 30-seater hybrid planes. The short range of such planes is less of a problem for a small country like Iceland, but overseas flights bringing tourists there remain a bigger challenge.

More problematic is Iceland's massive fishing fleet. One way to green the fleet would be switching to renewable methanol. In 2012, an Icelandic company called Carbon Recycling International (CRI) built the first ever renewable methanol factory next to the HS Orka geothermal plant at Svartsengi – the source of the water that creates Iceland's famous Blue Lagoon. This small demonstration plant split water to make hydrogen, then combined this with small amounts of $CO_2$ from the geothermal plant, which is brought up by the hot water, to make "e-methanol".

**2040**

**Year by which Iceland aims to become carbon neutral**

However, the Svartsengi geothermal plant doesn't bring up enough $CO_2$ to make commercial-scale production of methanol viable at this site. "We decided to focus our resources on supporting the deployment of our technology at a larger and global scale," says Kristjana Kristjánsdóttir at CRI.

The company designed the first commercial-scale factory for turning $CO_2$ and hydrogen into methanol, which began operating in China last November. This plant turns waste $CO_2$ from industry into 110,000 tonnes of methanol per year, replacing methanol usually made from coal. CRI estimates that it will reduce $CO_2$ emissions by 500,000 tonnes a year and has already begun work on a second plant in China.

While CRI is turning $CO_2$ into fuel, CarbFix – the company behind the pumping project I saw – is focused on storing it safely underground. "This is not [just] a promising idea, it's a tried-and-tested method," says Ólafur Teitur Guðnason at CarbFix, who hands me cores from drilling that show how the porous black rock beneath Hellisheiði fills up with white carbonates as the $CO_2$-rich water percolates through it.

For the Hellisheiði plant, CarbFix provides a way to safely dispose of the $CO_2$ that comes up with the hot water. The firm is also building the infrastructure needed to import $CO_2$ from Europe for mineralisation beneath Iceland. It aims to inject 3 million tonnes a year by 2031, and hopes to use the process at the many other suitable sites for mineralisation found around the world. Vast quantities of $CO_2$ could be locked away using the CarbFix approach, says Guðnason. "The potential is enormous."

MICHAEL LE PAGE

**The CarbFix injection site pumps carbon dioxide underground**

Some of this $CO_2$ could even be taken directly from the air. In fact, this is already happening on a tiny scale. Just a few hundred metres away from the Hellisheiði plant is an array of what look like giant air conditioners. This is the direct-air-capture pilot plant of Swiss company Climeworks, which is powered by the geothermal plant and sends the captured $CO_2$ to CarbFix to pump underground for mineralisation. There have been teething issues due to the severe Icelandic weather, but Climeworks is now planning to build a bigger plant in a location it has yet to reveal.

All of this makes it easy to see why other countries want to import Iceland's geothermal expertise. For instance, a company in China called Sinopec Green Energy was co-founded by Reykjavik-based firm Arctic Green Energy. Sinopec is now the largest geothermal district heating company in the world, providing centralised heating for 2 million people in more than 60 cities in China.

MICHAEL LE PAGE

**Beneath this geodesic dome, CarbFix sequesters carbon dioxide**

"Iceland is selling its know-how internationally," says Ríkarður Ríkarðsson at Iceland's national power company Landsvirkjun, which operates geothermal and hydro plants.

The soaring costs of heating in Europe have led to a surge of interest in geothermal, he says. While few countries have accessible sites that heat water to the high temperatures needed for generating electricity like Iceland, many have suitable locations for producing water warm enough for district heating systems.

In the UK, for instance, it has been suggested that geothermal could meet the country's entire heating needs. It isn't clear that the potential is this great, but it is certainly huge. And if Iceland's experience is anything to go by, investing in geothermal could bring huge benefits in terms of clean, cheap heating.

"The energy crisis has given a huge boost to Iceland's energy industry," says Halla Hrund Logadóttir, head of the National Energy Authority of Iceland. "All parties are behind the effort to go green, as they see the benefits more than ever thanks to the energy crisis." ▮

*Michael Le Page's trip was paid for by Green by Iceland, a government-funded organisation*

**Animal behaviour**

# Ichthyosaurs used a barren region of the ocean as an ancient nursery

**Michael Marshall**

A RICH deposit of fossilised marine reptiles called ichthyosaurs found in Nevada may be remains from a breeding ground dating back more than 200 million years. The creatures seem to have gathered in a quiet patch of sea where there would have been few predators.

The discovery hints that breeding behaviours seen in modern animals like whales were being performed by their reptilian equivalents in the dinosaur era.

Ichthyosaurs, which superficially resembled today's whales and dolphins, lived in the seas from about 250 million years ago in the Triassic Period until about 90 million years ago in the Cretaceous, while dinosaurs roamed the land.

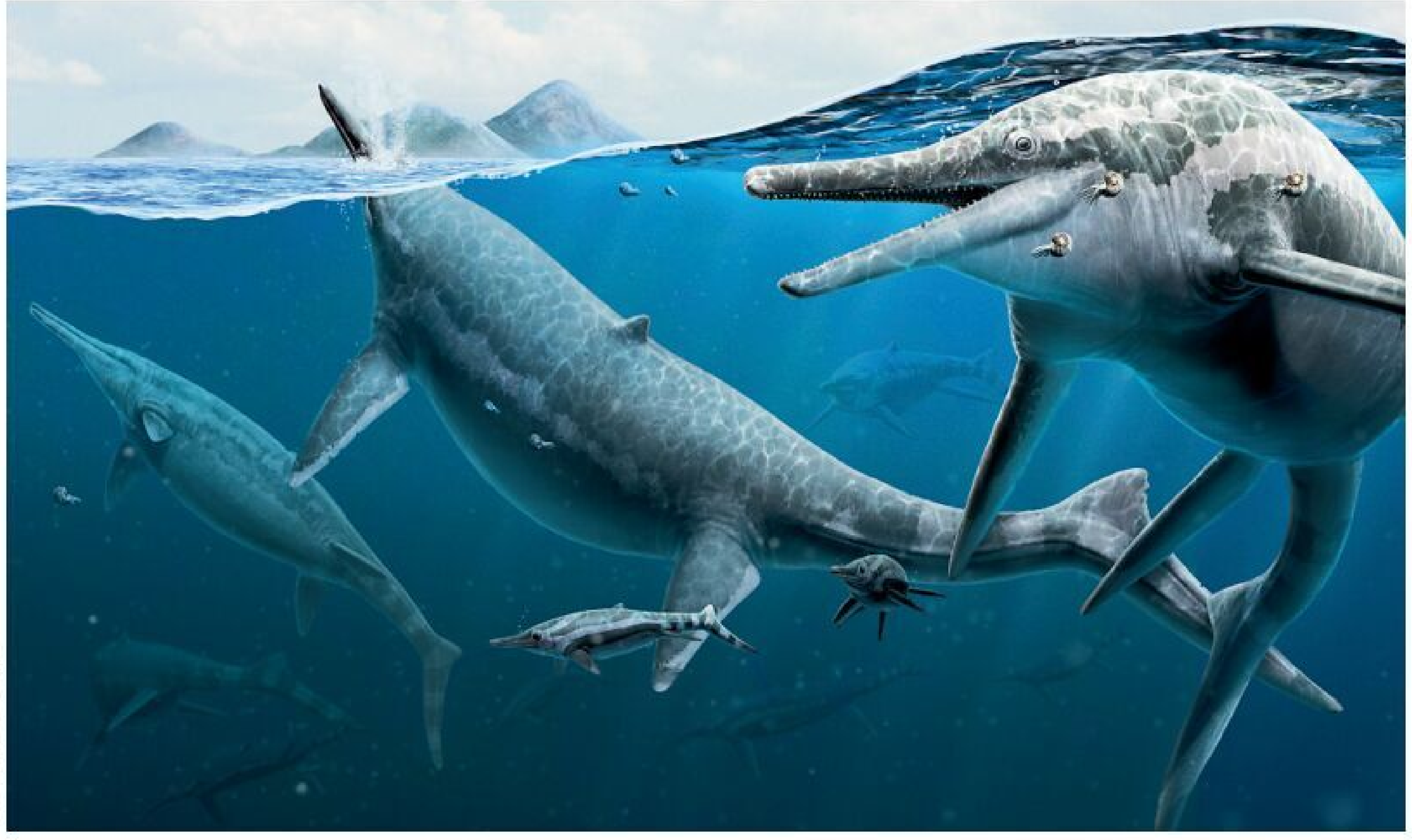
The Nevada ichthyosaurs were excavated between the 1950s and 1970s from the Berlin-Ichthyosaur State Park site by palaeontologists led by Charles Lewis Camp. His description of the animals was published posthumously in 1980, after which the specimens were largely ignored for decades.

These ichthyosaurs belong to a species called *Shonisaurus popularis*. They were between about 11 and 15 metres long and lived some 215 million years ago, near the end of the Triassic.

Camp had suggested that there had been a mass stranding, as can happen to whales and dolphins today. "He imagined that they were hunting around in the shallows and the tide had gone out, and they had got inadvertently left behind," says Neil Kelley at Vanderbilt University in Nashville, Tennessee.

This explained the absence of smaller animals like fish among the fossils, because they could have escaped even in shallow water. But it didn't fit the geological evidence, which showed that the fossils were laid down in deep water.

Kelley and his colleagues have now re-examined the evidence. They couldn't find direct signs of environmental disruptions like volcanic eruptions or low oxygen levels that might have killed the animals, he says.



**Ichthyosaurs lived in Earth's oceans for about 160 million years**

GABRIEL UGUETO

However, what team member Paige dePolo at the University of Edinburgh, UK, did find when she sorted through the fossils were baby ichthyosaurs.

The reanalysis revealed that there were a lot of adult ichthyosaurs, at least three juveniles or embryos and virtually no other animals present. The team suggests the ichthyosaurs sought out a quiet region of the ocean where there was little food because there would have been few predators to threaten their young (*Current Biology*, doi.org/grhrnk).

"The palaeontological evidence we have supports that there's not other things with backbones that might eat the babies in this area," says dePolo.

We can't be 100 per cent sure because the fossil record is open to interpretation, says Benjamin Kear at Uppsala University in Sweden. "Having said that, I think it's entirely plausible."

He says this fits other evidence, such as ichthyosaurs giving birth to only a handful of young, which hints at parental care. ▮

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**Health**

## Hundreds of genetic variants appear to raise the risk of gout

GOUT is often associated with eating certain foods, but it has now been linked to almost 400 gene variants in the largest study of its kind.

The condition, a form of arthritis, is caused by a build-up of uric acid, or urate, from the breakdown of molecules called purines. This causes urate crystals to form in joints, often in the big toe, leading to a painful inflammatory response.

Purines are made in the body and found in some foods and drinks, such as bacon and beer.

To better understand the role of genetics, Tony Merriman at the University of Otago in New Zealand and his colleagues analysed the genomes of more than 120,000 people with known or suspected gout and 2.5 million people without a gout diagnosis or any symptoms. The researchers described the participants' ancestry as being African, East Asian, European or Latinx, meaning people of Latin American ancestry.

The results linked 376 genetic variants to gout (medRxiv, doi.org/10/jqvh). The team used this information to predict the gout risk of more than 332,000 people of European descent, some of whom had the condition. When the researchers compared their genetic approach with one that uses the known risk factors of age and sex, the former tallied slightly better with those people who actually had gout, says Merriman.

"This study will significantly add to our understanding of the genetics of gout risk and may provide a road map to pathways that can be targeted for new gout therapies," says Owen Woodward at the University of Maryland. In the meantime, further research is required, he says.

> "This research may provide a road map to pathways that can be targeted for new gout therapies"

Merriman says the first part of the study included people from several ethnic backgrounds, but most were European. "We need more data for people of non-European ancestry," he says. To help address this, the team is now studying a larger group of people of African descent. ▮

**Carissa Wong**

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**Technology**

## Super-absorbent towel beats paper

A THIN towel that expands into a jelly-like blob can absorb liquids three times as well as paper or cloth-based products.

Hydrogels – meshes of long molecules linked together in a network – can absorb and hold large quantities of water, but when they dry out, they become brittle and so aren't suitable as paper towels. Now, Srinivasa Raghavan at the University of Maryland and his colleagues have produced a dry, absorbent hydrogel that stays intact even while rolled up.

The team tested how well the sheet absorbed water compared with kitchen towels and cloths and found it could absorb more than three times as much and didn't drip (*Matter*, doi.org/grh5mn).

The gel sheet can't be reused, but Raghavan sees it as an alternative to kitchen roll. **Alex Wilkins**

**Animal behaviour**

## Spiky genitals stop wasps being lunch

FEMALE wasps have a venomous sting to discourage predators, but males don't. Instead, male mason wasps have an alternative defence: using their spiky genitals to attack animals that try to eat them.

Male wasp genitals include an aedeagus, the insect version of a penis, and a pair of spines. Shinji Sugiura and Misaki Tsuji at Kobe University, Japan, put single male mason wasps (*Anterhynchium gibbifrons*) in a container with a tree frog (*Dryophytes japonicus*). On every occasion, the frog attacked the wasp, but then rejected it 35 per cent of the time.

The wasps were seen to pierce the mouth or face of the frogs with their genitalia while being attacked. When tree frogs were put in a container with male wasps that had been castrated, they all ate the wasps (*Current Biology*, doi.org/grhrnj). **Matthew Sparkes**

DINA RUDICK/THE BOSTON GLOBE VIA GETTY IMAGES

**Neuroscience**

## Cochlear implants could become more effective

WE MAY be closer to understanding why cochlear implants don't promote hearing in every deaf or hard of hearing recipient. A study in rats suggests that neuron activity in the brainstem influences how they respond to sounds after an implant.

Cochlear implants, shown in the image above, have two parts, with one inserted into the cochlea bone in the inner ear. Here, it turns sounds into electrical signals that stimulate the auditory nerve, providing the sensation of hearing. For some people, the implants are effective almost immediately, while in others this can take weeks or even years.

To better understand why these varying responses occur, Erin Glennon at the New York University Grossman School of Medicine and her colleagues inserted cochlear implants into 16 rats with induced deafness. The researchers then monitored the activity of neurons in a structure of the rats' brainstem called the locus coeruleus (LC). "This brain area is the main source of noradrenaline," says Robert Froemke at NYU Langone Health.

The rats initially had varied responses to the implants, with the researchers noticing the animals' LC activity predicted when they began responding to sounds. When the LC was then artificially stimulated, the differences in the rats' LC activity disappeared and they all responded to sounds (*Nature*, doi.org/jq3w).

According to Froemke, activity in the LC promotes neuroplasticity, the brain's ability to alter its structure and function, making it more sensitive to sounds.

"The results open the possibility of using noradrenaline to promote the outcome of cochlear implants," says Victoria Bajo at the University of Oxford. **Moheb Costandi**

## *Really* brief

JUNIORS BILDARCHIV GMBH/ALAMY

### Bacterial infection aids ticks in winter

A bacterium that causes Lyme disease may help the ticks it infects live through cold conditions. Deer ticks (*Ixodes scapularis*, pictured) in Nova Scotia, Canada, that were infected with *Borrelia burgdorferi* bacteria had a 22 per cent risk of dying over winter, yet uninfected ticks had a 51 per cent risk (bioRxiv, doi.org/jq2m).

### Extra rod cells help fish see in dim light

Nocturnal fish can have as many as 28 layers of light-sensitive rod cells at the back of their eyes, known as a multibank retina. This results in them having faster vision and greater sensitivity to light. The same adaptation may enable deep-sea animals to see in the dark (bioRxiv, doi.org/jq2n).

### Speedy animals perceive time faster

The eyes of fast-moving creatures process more frames per second than slower ones. Dragonflies can detect 300 flashes of light per second, which is about 400 times faster than starfish. A comparison of more than 100 species was presented at a British Ecological Society meeting on 20 December 2022.

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Sylvia Kalaba in Kundamfumu village in Zambia is using her solar light to cook in the evening

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We know that every time someone switches on a solar powered light, it's an instant win for both people and the planet, so we have made it our mission to light up every home, school and clinic in Africa by the end of the decade with clean, safe, solar power. But we can't do it alone. When you help get one of our solar lights into the hands of a farmer, it means they can sort through their soya beans even after the sun sets. For a child it means they can get ahead in school because they can do their homework in the evening. And for a midwife, it means she can deliver babies safely through the night.

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# Views

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The feeling of awe can help us fight climate change p28

**Culture columnist**
**Sally Adee** explores sci-fi that probes animal intellect p30

**Comment**

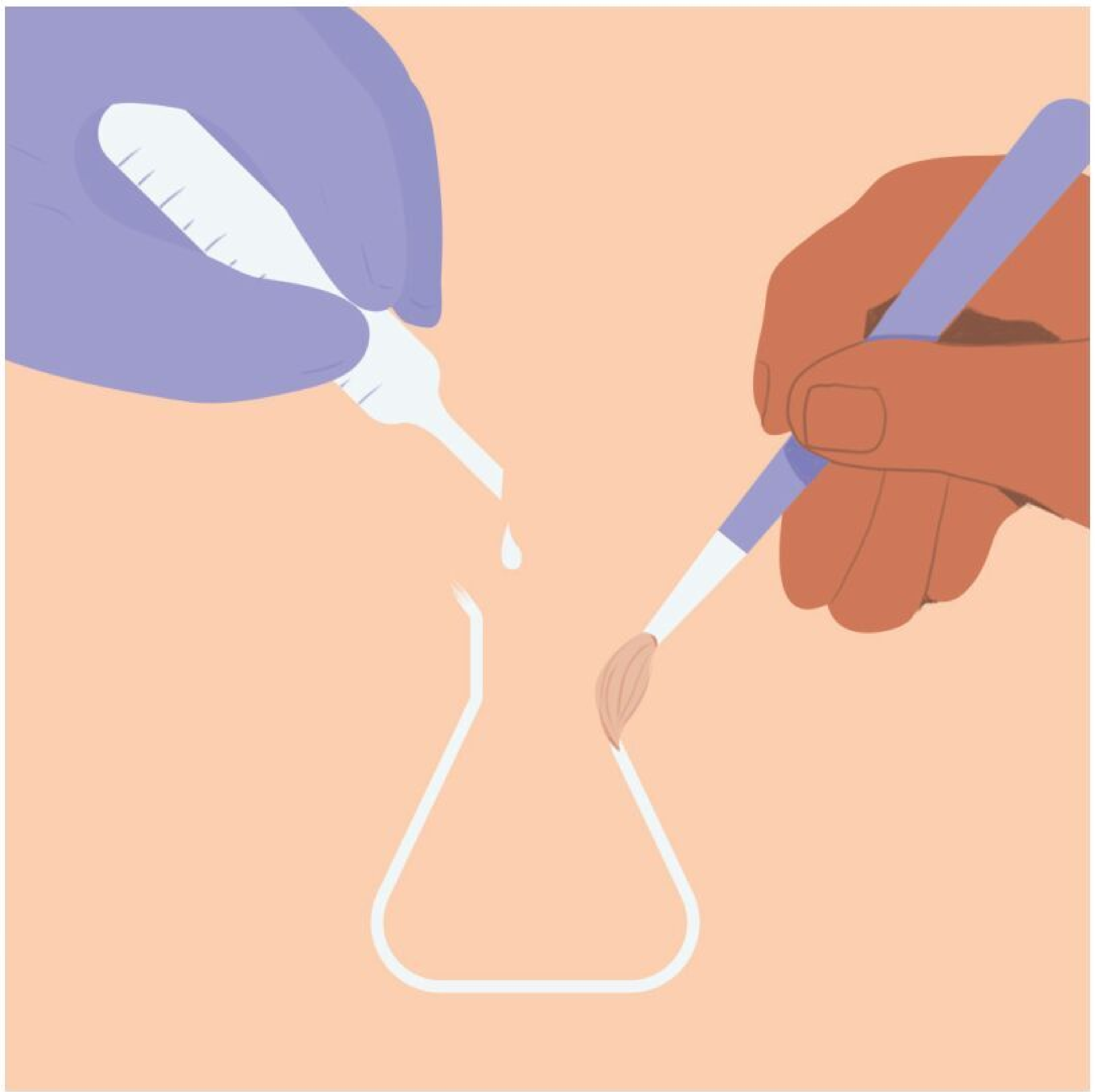
# The art of science

Science is key to addressing global health challenges, but it needs to work with the arts to reach all who could benefit, says **Danielle Olsen**

IN THE Science and Industry Museum in Manchester, UK, Lemn Sissay's vibrant poem *The World Wakes* exploded with the possibilities of 2D materials science following the isolation of graphene. At the Ho Chi Minh City Museum of Fine Arts in Vietnam, Lêna Bùi's film *Where Birds Dance Their Last* reflected on the beauty and vulnerability of Vietnamese feather farms after avian flu. During the University of Global Health Equity's Hamwe Festival in Kigali, Rwanda, Ellen Reid's audio experience *Soundwalk* was shared in a hopeful discussion about music, parks and mental health.

A poem, a film and a musical map. All publicly accessible and all creating space for meaningful conversations about research. These are a few of the things I have helped bring to life over the years, working at the intersection of scientific research, the arts and advocacy to support science in solving global health challenges.

Science is key to addressing these issues. But it isn't the only key. To achieve its potential and for its advances to be implemented and reach all who could benefit, science depends on trust and good relationships. People might not always see science as relevant, trustworthy or meaningful to their lives. There are reasons why some see science as having a chequered past and systemic biases, from nuclear weapons to eugenics, and are therefore uninterested in, or suspicious of, what it propounds. Others feel excluded by the impenetrability of hyperspecialist knowledge.


MICHELLE D'URBANO

In its capacity to build upon and test an evidence base, science is powerful, but – and not for want of trying – researchers and funders haven't been as good at ensuring this evidence base responds to the needs and interests of diverse communities, or informs policy makers to take action.

Science might be perceived as distancing itself from the personal, the poetic and the political, yet it is precisely these qualities that can be most influential when it comes to public interest in a topic or how a government prioritises a decision.

A moving story well told can be more memorable than a list of facts. This is where the arts come in. Artists can give us different perspectives with which to consider and reimagine the world together. They can redress the proclaimed objectivity in science by bringing stories – subjectivities – into the picture, and these can help foster a sense of connection and hope.

In 2012, I set up artist residencies in medical research centres around the world. Bùi was attached to the Oxford University Clinical Research Unit in Vietnam. The head of the zoonoses team at the time was delighted, finding that Bùi, as a Vietnamese artist, had licence to be in, and share useful insights from, villages where infectious disease researchers weren't welcome.

Six years later, to mark the centenary of the flu pandemic, I led Wellcome's Contagious Cities programme, which established artist residencies in Berlin, Geneva, Hong Kong and New York and worked in partnership with cultural institutions to support locally led explorations of epidemic preparedness. Covid-19 threw this work into stark relief, and has also informed our Mindscapes programme. This is currently sharing experiences of mental health through the work of artists around the world, such as writer Priya Basil, who is travelling to places where biomedical and traditional approaches to mental health meet, aiming to compile a new atlas of mental health.

With pandemic, climate and mental health crises upon us, rising inequality and what feels like an increasingly fractured world, never has there been more need to build and nurture hopeful and imaginative spaces to grow human connection and shared purpose for the common good. Science and the arts can work hand in glove to achieve this. ▮

Danielle Olsen is cultural partnerships lead at Wellcome in London

**Field notes from space-time**

# The heart of quantum mechanics

There are alternative interpretations to wave-particle duality, but we don't teach them. This limits our students, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an assistant professor of physics and astronomy, and a core faculty member in women's studies at the University of New Hampshire. Her research in theoretical physics focuses on cosmology, neutron stars and particles beyond the standard model

## Chanda's week

**What I'm reading**

*I just finished Bolu Babalola's* Honey and Spice *and I loved it so much that I bought it for a few friends.*

**What I'm watching**

*Sometimes, it feels like I live in the* 90 Day Fiancé *universe. (Insert embarrassed emoji.)*

**What I'm working on**

*Preparing my first ever course on quantum mechanics.*

QUANTUM physics – known to practitioners as quantum mechanics – is a subject that physicists learn in a rather peculiar way. We all learn to calculate using its mathematical framework, but that doesn't mean we can really explain what it all means. If we go far enough in our education, we get the opportunity to see just how accurately these calculations match experimental results, so we learn to trust that they are correctly describing reality.

But how can a cat be both alive and dead inside a box before we look at it? We can do calculations that are consistent with this interpretation of the equations, but what can that possibly mean, physically? Quantum mechanics is filled with what we might consider surreal: it is hard for us to make rational sense of it, yet the mathematics implied by our experimental results commands us to draw certain conclusions.

One classic experimental result is that light behaves like both a particle and a wave. Despite being most famous for special relativity and general relativity, Albert Einstein actually won the 1921 Nobel prize for his contribution to understanding this wave-particle duality, which became a cornerstone of quantum mechanical theory. Einstein's work combined with that of Max Planck to show that light came in quanta: *lichtquanten*, or discrete packets of energy known as photons. These photons acted like particles, but also acted like waves.

The most accessible way to explain how this is possible is using the famed double-slit experiment, something students can now do in their undergraduate lab course. Lasers are shot at a plate with parallel slits. The pattern that forms on the wall behind the slits is the kind we would expect to see with a wave. But when observed closely, the pattern is comprised of discrete, individual absorption points: what we would expect from something acting like a particle, not a wave. Light, it turns out, is both.

A century ago, a PhD student named Louis de Broglie dramatically broadened the quantum revolution that was under way. In 1923, de Broglie published a series of articles putting forward the hypothesis that wave-particle duality was a property of all matter, not just light. He wrote down an equation that connected a particle's mass and velocity with a wavelength, the distance that a wave repeats over. This became the foundation of his 1924 PhD dissertation. Three years later, George Paget Thomson confirmed that electrons behaved in a manner consistent with de Broglie's claims. In 1929, de Broglie won a Nobel prize for his contribution to physical knowledge.

> "Why do we exclude the conceptual challenges of quantum mechanics from the classroom?"

We teach de Broglie's equation – and Einstein's precursor to it – multiple times in our curriculum at the University of New Hampshire. Students see it in a modern physics course, a baby steps-style introduction to advanced concepts in physics. They then see it again in thermodynamics and in their introduction to quantum course. I also teach it in my stellar astrophysics course. This is all to say that a physicist is expected to be very familiar with wave-particle duality and have facility with its mathematical form.

Something we don't teach in classes is that, actually, there are alternative interpretations to wave-particle duality, including one advanced by de Broglie himself and fully developed later by physicist David Bohm. In this picture, a wave and particle simultaneously exist. There are still other ideas where you can explain the data entirely by using a wave model, with no particle necessary.

I came of age thinking this was a problem for philosophers, not physicists. Then I turned into a physicist who also did philosophy, and that boundary seemed increasingly strange to me. My interest in how race, gender and class shape outcomes in physics led me to question why we exclude the conceptual challenges of quantum mechanics from the classroom. The generous explanation is that we only have so much time with students and we have to make difficult choices about what to teach.

But it is also the case that students come to our classrooms in part because they are enthralled by the strangeness of physical theories like quantum mechanics. Unfortunately, from an economic perspective, there is a lot to be gained by knowing how to calculate and ultimately engineer with these ideas, even if we struggle to make conceptual sense of them. There are no obvious physical applications to trying to understand the conceptual heart of the issue.

I completely understand the logic at work here, but it is also so obviously limiting. Students are cheated out of an opportunity to think deeply about the surprising ways of the physical world at the smallest scales, and that is itself an educational failure. ▮

This column appears monthly. Up next week: Graham Lawton

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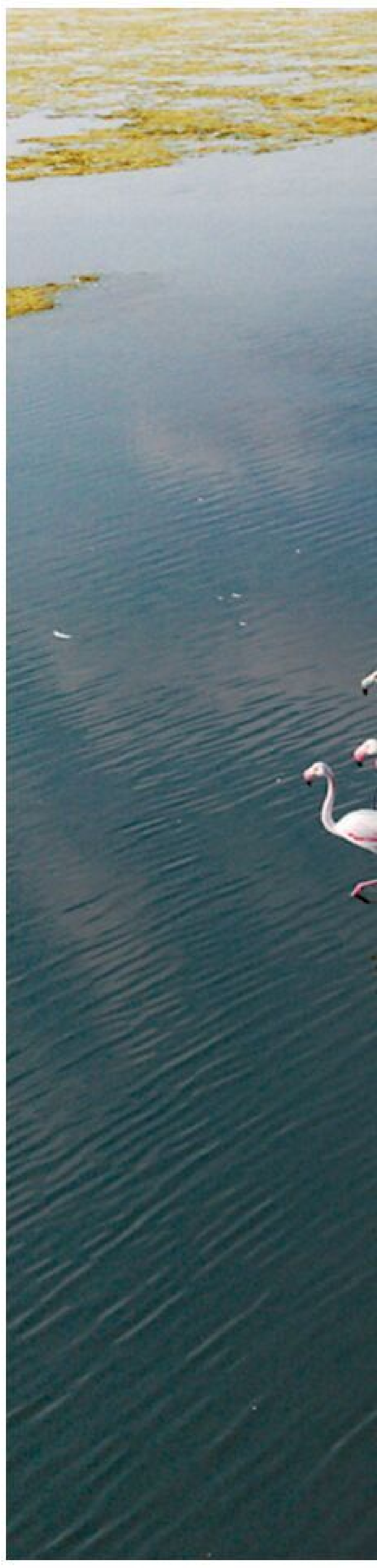

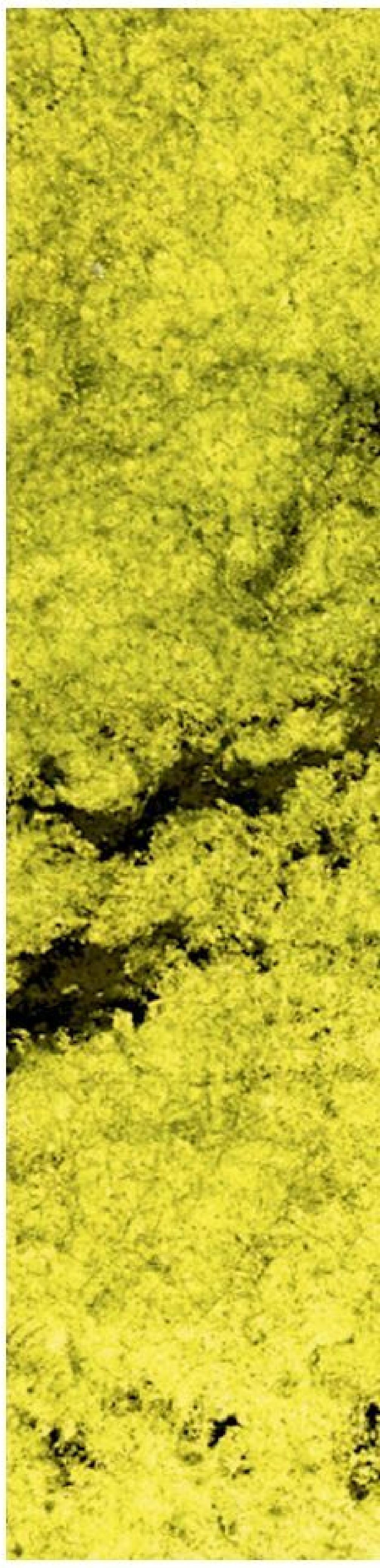

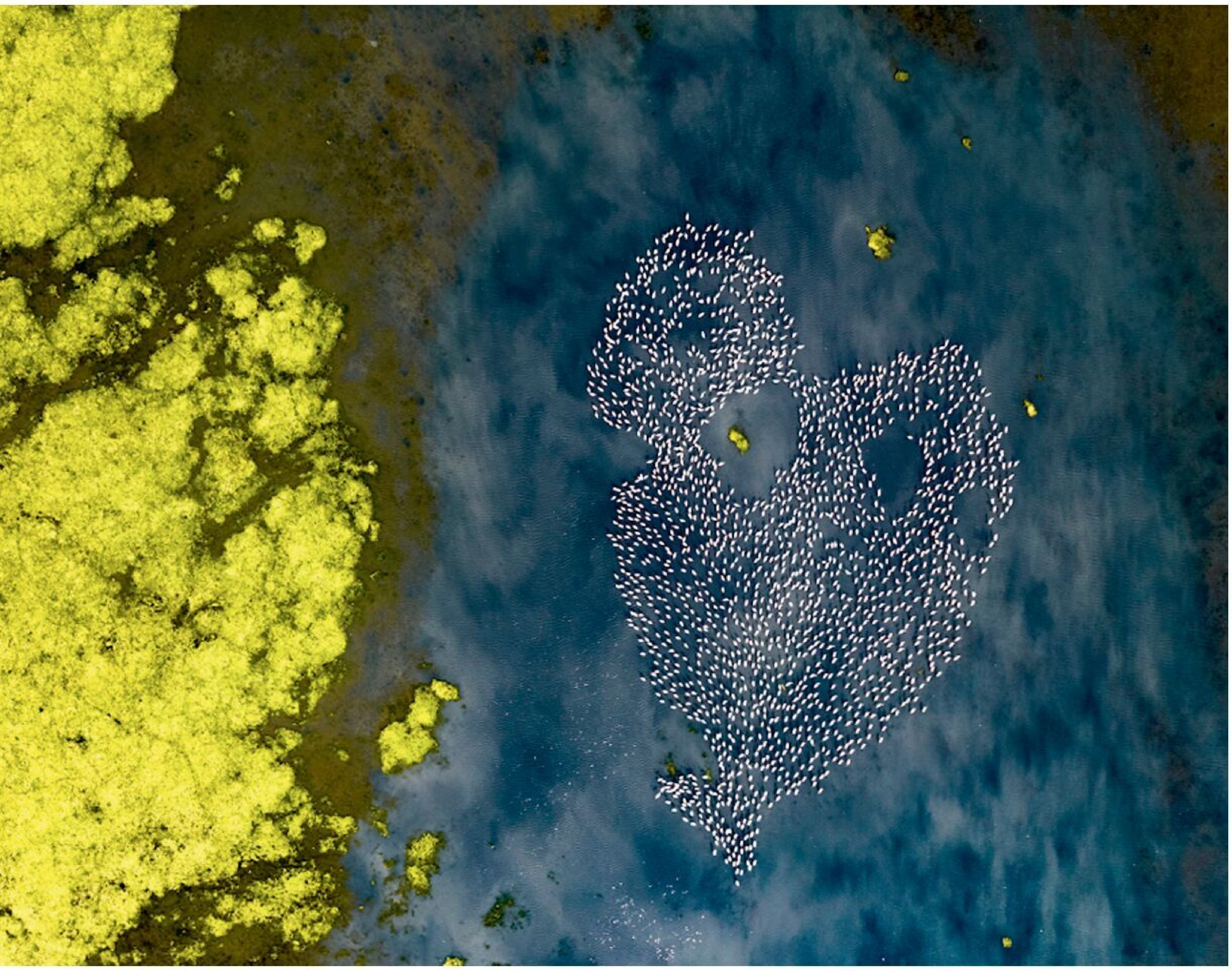

# Pretty in pink

**Photographer Raj Mohan**

THESE glorious formations of flamingos, captured by photographer Raj Mohan, add a dazzling wash of pink to Pulicat Lake in Tamil Nadu, India.

Although flamingos aren't generally migratory, their colonies aren't always permanent either, and the birds will sometimes search out new breeding grounds in their thousands due to factors like changes in climate or water level. Here, they have chosen to settle in a 750-square-kilometre expanse of shallow water, one teeming with fish and plankton.

Flamingos tend to fly in a "V" formation during such journeys, which saves them energy so they can travel further. Members of the flock take it in turns to lead the V and take on the brunt of the wind resistance, while those behind each fly slightly above the bird in front of them, further reducing drag. Down on the ground, formations can take on more creative shapes, as shown by the heart-like arrangement in the image at bottom right.

Mohan was spurred to document these epic avian congregations after wondering why he only saw the flamingos at the lake between November and May. Now, he spends time each year observing the birds' movements and photographing their formations – something that isn't necessarily challenging, but requires a lot of patience, he says.

"The way they always stick together in colonies is fascinating," says Mohan. "Being an aerial photographer, I wanted to know what it's like to see these colonies from above. It's amazing to watch them making different formations, and those shapes are pure art!" ▮

**Gege Li**

## Editor's pick

### Don't forget the geopolitics of unlimited fusion power

**17/24 December 2022, p 28**

*From Carl Zetie,*
*Raleigh, North Carolina, US*

**With optimism over fusion power in the news again, I may be the only Cassandra who fears this won't lead to the low-carbon, cheap-energy utopia we hope for.**

**If successors to massive intergovernmental collaborations like the ITER reactor are the future, rather than the small-scale projects being pursued in the private sector, these machines will be incredibly expensive to build, operate and maintain, so much so that possibly only three governments – those of the US, European Union and China – along with perhaps two or three very rich corporations, will be able to afford to deploy them.**

**The advantages of low-cost energy will then be available only to richer nations and those smaller countries willing to swear fealty to them, with poorer, smaller or non-aligned countries left to make do with dirty and expensive carbon fuels, while no doubt continuing to be chided for their polluting ways.**

**Unless the benefits of fusion are made available to all, regardless of political allegiances, the structural inequities of the world will become worse than they are. That is hardly the clean, cheap, climate-friendly utopia we are being promised.**

### High time to firm up the outer space treaties

**Leader, 3 December 2022**

*From S. Shaw, Kendal, Cumbria, UK*

Amid talk of greater access to outer space, we must remember that space, like much of the sea, doesn't belong to any one country. As the number of launches soars, we need to firm up international agreements in relation to the use of space for both scientific and commercial purposes.

To take just one example, there are a finite number of locations for the geostationary orbits of communications satellites, as these must all be positioned over the equator and at the distance from Earth at which the period of their orbit is exactly one day. Who may put a satellite in such an orbit?

The experience of the way in which terrestrial empires were set up is a good example of how not to proceed beyond Earth. Without concrete agreements, rights in space may be claimed by planting a flag and settling sufficient armed personnel to defend the claim, whether it is made by a country or a hubristic billionaire.

### Try this mix for a liquid telescope on the moon

**10 December 2022, p 41**

*From Luce Gilmore, Cambridge, UK*

In your report on the return of liquid mirror telescopes, you say that mercury would be too dense a material for building such an instrument on the moon.

Why not use a sodium-potassium alloy, with a melting point of -4°C? These metals are cheap, very low density, won't tarnish in a vacuum and reflect light better than mercury.

*From Janet Gunn,*
*Nokesville, Virginia, US*

You mentioned that building a liquid mercury telescope was first attempted in the late 19th century, but didn't give any more details.

I remember reading some time ago about a liquid mercury mirror telescope built in the 19th century by William Parsons, 3rd Earl of Rosse, at Birr Castle in Parsonstown, Ireland. It was reported that a horse trotting down the road a mile away could cause vibrations that negatively affected the mirror. Parsons was also responsible for building, in 1845, the 72-inch conventional reflector telescope known as the Leviathan of Parsonstown, which helped to identify the first spiral nebulae.

### Consumers are as guilty in the court of climate change

**Letters, 3 December 2022**

*From Martin Greenwood,*
*Perth, Western Australia*

Chris Lee asks us to make fossil fuel companies responsible for paying reparations to lower-income countries over the damage that has been inflicted on them by climate change.

Unless he grows all his own food, walks everywhere, doesn't use electricity and declines to buy anything from a shop that is made in a factory or delivered by a truck, Lee will, like every other resident of a Western nation and the great majority of residents of lower-income nations, be reliant on fossil fuels for much in his life.

In that sense, we are all complicit in the so-called crime of fossil fuel consumption.

### We are going about robot cars totally the wrong way

**17/24 December 2022, p 13**

*From Bryan Lovell,*
*Chambéry, France*

Amid pessimism that self-driving cars you can buy will ever truly come to pass, recall that today's autonomous car development has been orientated towards making them adapt to our environment. This has hampered progress.

How much simpler it would be to adapt the environment to self-driving transport. What we require are standards and protocols for autonomous cars to communicate electronically with each other and their surroundings. City administrations could install the infrastructure required and manufacturers would build cars to meet those requirements. What is needed is an organisation willing and able to take on this challenge.

Perhaps the European Union could do it. It is a big market that could reward vehicle-makers investing in this approach.

### Sorry, there is no you, only what you do

**10 December 2022, p 36**

*From Rhiannon Rual,*
*Llanfwrog, Denbighshire, UK*

Daniel Cossins wants to find out his true nature. Any existentialist would tell you that this is a fruitless exercise, as there is no essential you. Instead, you are free to embrace self-determination through your actions. As for letting others define who you are, I leave the response to Jean-Paul Sartre: "*L'enfer, c'est les autres!*" (hell is other people).

### For splash-free toilets, just look to the Victorian era

**3 December 2022, p 21**

*From Mark Cargill,*
*Alcester, Warwickshire, UK*

Zhao Pan's splash-free urinal reminds me of a Victorian design. My parents-in-law had an old outside loo. On the back of the bowl, just above the water line, was an image of an insect. Men, being men, aimed for this and, lo and behold, no splashing. ▮

### Want to get in touch?

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### For the record

**▮ A teenager called Alyssa was the first person to be treated with CRISPR base-editing for leukaemia (17/24 December 2022, p 8).**

**▮ Juicy Marbles, which produces plant-based "prime meat", is a Slovenian start-up (17/24 December 2022, p 55).**

**▮ Beth Pike is director of the Marine Protection Atlas at the Marine Conservation Institute (17/24 December 2022, p 62).**

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# Restoring the wonder in life

Taking the feeling of awe seriously can add meaning to our lives – and even help us engage with huge problems like climate change, finds **Sarah Phillips**

**Book**
**Awe**
**Dacher Keltner**
**Allen Lane**

IN JANUARY 2019, when Dacher Keltner was present at his younger brother Rolf's bedside during the last moments of his life, he felt many things. Perhaps the most surprising was awe: "I felt small. Quiet. Humble. Pure. The boundaries that separated me from the outside world faded."

Awe is something that Keltner, a professor of psychology at the University of California, Berkeley, has now considered extensively. In 1988, when he asked his mentor Paul Ekman – renowned for his pioneering work on facial expressions – what he should research, Ekman answered "awe".

He rose to the challenge and Keltner's latest book, *Awe: The transformative power of everyday wonder,* takes on this under-appreciated human experience, documenting his own inquiries alongside a wider context for awe, including the work of Charles Darwin, Jean-Jacques Rousseau and William Wordsworth.

Keltner defines awe as "being in the presence of something vast and mysterious that transcends your current understanding of the world". With social psychologist Yang Bai, also at the University of California, Berkeley, Keltner asked 2764 people in 26 countries to respond to his definition by documenting their own encounters with awe.

These varied wildly, from first seeing the ocean to admiring someone's strength in adversity. Keltner and Bai categorised their findings into "Eight Wonders of Life" that trigger us to experience awe: moral beauty, collective effervescence, nature, music, visual design, spirituality and religion, life and death, and epiphany. Each chapter of *Awe* is devoted to one strand.

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**Mountain peaks are a sure way to create feelings of awe**

> "One of Keltner's big ideas is 'everyday awe'. An 'awe walk' to take in your environment is an ideal start"

Strikingly, Keltner finds that money, gadgets and social media didn't arouse such strong feelings of awe among the interviewees. Instead, other people's courage is its most common trigger.

Keltner speaks to artists, prisoners, sportspeople, musicians, scientists and spiritualists in search of awe and why it matters. It is especially important, Keltner argues, because of its power to create a sense of community around our appreciation of it.

As director Steven Spielberg tells Keltner when he explains his focus on film-making as a means to convey wonder, "we are all equal in awe". For me, if there is one downside to this thesis, it is the fact that people will be unequally exposed to awe because they have less access to the experiences that induce it, such as geographical wonders, stunning nature or transformative culture.

Contemplating how his grief for Rolf left him "aweless", as his "companion in awe was no longer around", Keltner revisits the American River, which winds its way from the Sierra Nevada mountains to Sacramento. It was where the pair rafted as children. On this trip to experience "wild awe" – the fine line between fear and wonder – Keltner was accompanied by students and military veterans with post-traumatic stress disorder (PTSD). A week later, they still felt its benefits: a reduction in stress generally and in symptoms linked to PTSD.

The descriptions of the brothers' youthful experiments with psychedelics together are particularly vivid. Keltner classes these under spirituality in his eight categories, writing that nothing (apart from birth and death) is guaranteed to induce awe quite as much as those drugs.

In essence, Keltner has produced a workbook for living a more awe-filled life. One of his big ideas is "everyday awe". An "awe walk" – a stroll taken while mindfully appreciating your surroundings – is an ideal start.

He cites studies where David Attenborough's TV series *Blue Planet* was used to show people awe-inducing landscapes and gauge their reactions. Perhaps the great challenge of encouraging people to engage and take action on climate change could be overcome by harnessing awe.

Keltner also describes being consulted by the makers of the animated film *Inside Out* to inform its exploration of the workings of our feelings. Awe didn't make the cut, but Keltner believes the time is ripe for it to feature in a sequel.

Overall, *Awe* makes a persuasive case for this neglected feeling and for a more meaningful existence with it at the helm. ▮

Sarah Phillips is a journalist based in Norfolk, UK

# Successful invaders

From 30-metre-long tapeworms in blue whales to leeches living in hippos' anuses, the story of parasites is riveting, says **Gege Li**

**Book**

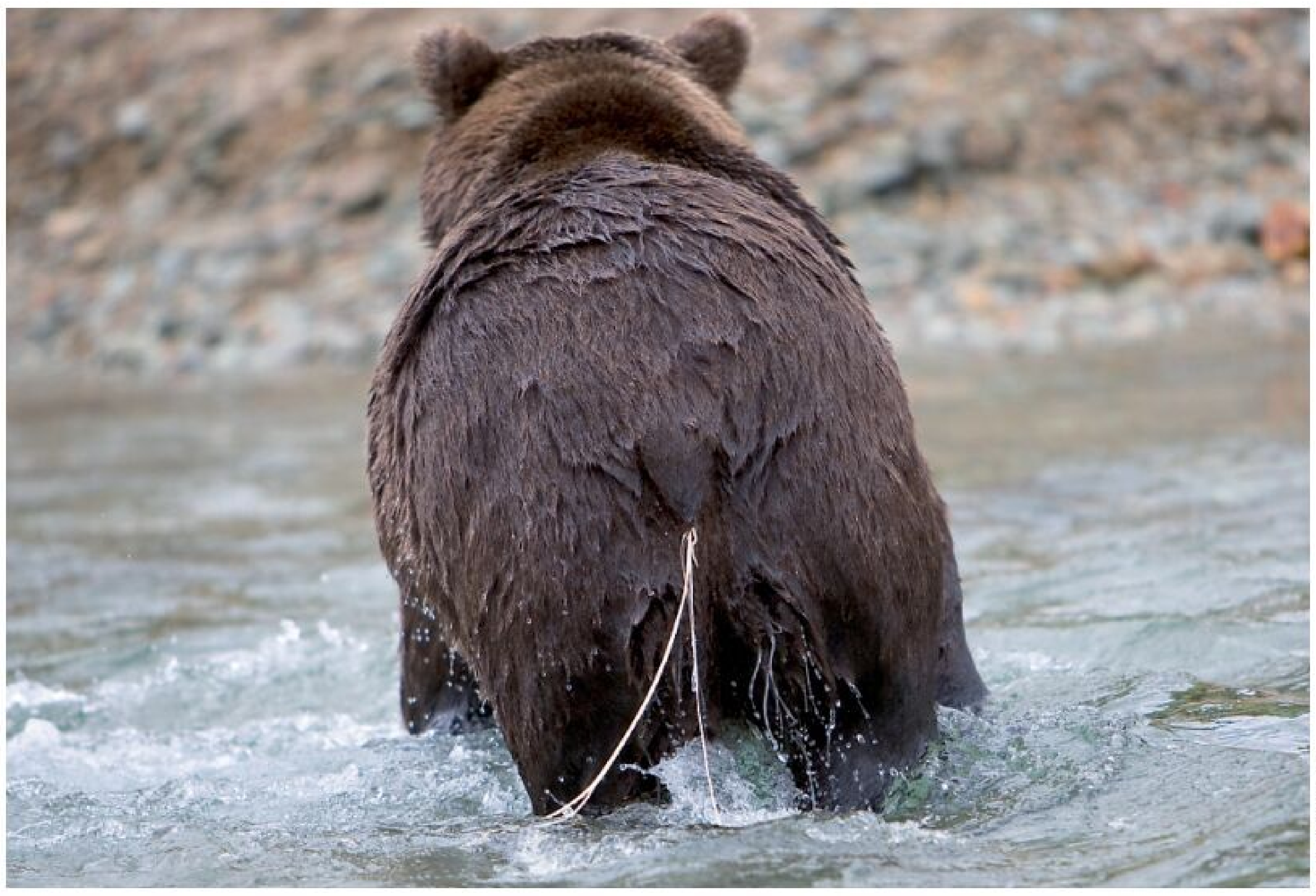
**Parasites: The inside story**
**Scott L. Gardner, Judy Diamond and Gabor Racz**
**Princeton University Press**

WHAT goes on the list of the most abundant living things on Earth? Parasites should surely make the cut. They live within us and many other animals, as well as in plants and fungi, and slip under the radar while infiltrating almost every food web and ecosystem. They are mind-bogglingly diverse, with hardy and sometimes extraordinary ways of living and reproducing in their hosts.

*Parasites* by Scott L. Gardner, Judy Diamond and Gabor Racz, all at the University of Nebraska State Museum, Lincoln, explores the world of parasitism and the ingenious tactics that have made it, according to the authors, the "most successful lifestyle on Earth".

Such a feat is largely due to the ability of parasites to hop between hosts and exploit events such as species migration. From mussels in fish gills and 30-metre-long tapeworms in blue whales to the leeches that live in the anuses of hippos, parasites will sometimes pop up in places that even trained parasitologists least expect them.

A broad fish tapeworm escapes out of the anus of its host, an Alaskan brown bear


SCOTT DAVIS

This fascinating book touches on various types of parasite to illustrate how they are entrenched. It includes three key players, all worms: nematodes, flatworms and the behaviour-manipulating thorny-headed worms, which can make host insects and crustaceans bend to their will to increase the chances that they will be passed on.

It isn't just animals that are parasites: the evolution of parasitic plants and fungi is "evidence that parasitism arises repeatedly as a sustainable lifestyle", say the authors. In fact, parasites have been pulling the strings throughout human history. For example, the first widespread public health campaign in the US was aimed at eradicating hookworm infections in the early 20th century.

If you are having a hard time visualising such critters, the book comes with photos of some suitably unpalatable parasites, along with the animals and landscapes in which they are found.

But despite the great success of parasitism, the authors explain that parasites are still understudied – and some of them are even under threat. As they point out, "our knowledge of the Earth's biodiversity catalog is still so incomplete that many species will vanish without ever having been identified. This is particularly true of parasites, since only a small fraction of them have been described."

Time is short before climate change "burns the library" of biodiversity for good. The authors are calling for the same enthusiasm to be adopted in citizen science for parasites as it is with documenting other organisms, like birds, in order to untangle their mysteries and better understand how to control the diseases some of them cause, as well as to enrich our knowledge.

With its detailed accounts of these intriguing organisms, their modes of infection and transmission, and the scientific studies that have been undertaken to understand them – including some by Gardner himself – the book makes a case that parasites aren't always "the bad kids on the block".

This message might have been more impactful had the authors given more space to the mind-bending capacities of parasites, and to parasites other than worms, rather than focusing on their most everyday trick: infecting hosts.

After several repetitions of what is a very similar infection process, albeit with different parasites, the book ends up feeling a bit formulaic and you may wonder whether the writers are doing justice to the full flamboyance of their subject.

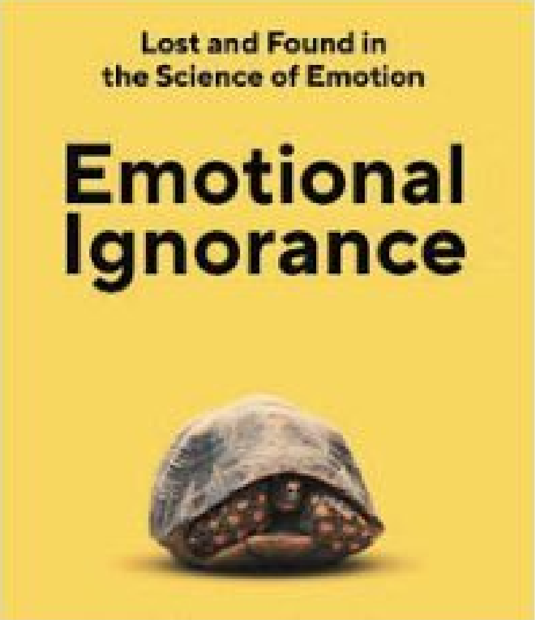
Even so, it is hard to overstate these organisms' often-invisible power and influence over the world and so many of its inhabitants. One thing is certain: you won't look at parasites in the same way again. ■

Gege Li is a writer based in London

## *Don't* miss

**Watch**

**The Last of Us** moves from award-winning video game to TV show, with Pedro Pascal (pictured) as Joel Miller, a smuggler who escorts a teenage girl, Ellie (Bella Ramsey), across a post-apocalyptic US. On HBO from 15 January.



**Read**

**Emotional Ignorance** by neuroscientist Dean Burnett tracks the author's journey after the death of his father from covid-19, as he explores where our emotions come from and what purpose they serve. On sale from 12 January.

**Visit**

**The Science of Dreams** reveals how and why we dream, and how to enhance our dreaming lives, says neuroscientist and doctor Jonathan Iliff. His talk is in Brighton, UK, at the Brighthelm Centre on 14 January at 4.30pm GMT.

TOP: HBO/WARNER MEDIA; LOWER: PAUL CRAFT/SHUTTERSTOCK

**The sci-fi column**

# Animal uprising

Imbuing animals and robots with sapience and self-awareness is a common theme in sci-fi. Annalee Newitz's new novel shows how this can go very wrong – and asks whose intelligence is being used as the template, finds **Sally Adee**

Sally Adee is a technology and science writer based in London. Follow her on Twitter @sally_adee

TITHILUADTHONG/SHUTTERSTOCK

**Book**

**The Terraformers**

**Annalee Newitz**

**Tor Books**

**(on sale 2 February)**

## Sally also recommends...

**Books**

**Collision**

**Edited by Rob Appleby and Connie Potter**

**Comma Press**

*This anthology showcases stories written by scientists working with well-known sci-fi writers. The jumping-off point is science from the CERN particle physics lab in Geneva, Switzerland.*

**Downfall**

**Louise Carey**

**Gollancz**

*The final book in a cyberpunk trilogy about what cities would look like if they were run by tech corporations.*

IN A deep future tens of thousands of years from now, animals have been brought into the so-called Great Bargain: in saving Earth from the consequences of the Anthropocene, a deal has been struck between all creatures, and humans now include everyone in managing the shared land.

But to participate, you need to be a person, and for that you must pass an intelligence assessment. So while relations between species look much more egalitarian than they did – with wisecracking robots working closely alongside talking animals and humans – *Homo sapiens* still calls the shots. In fact, the closer you look in *The Terraformers*, the ambitious new novel from *New Scientist* columnist Annalee Newitz, the more familiar things become.

Destry is an environmental ranger on patrol across a planet under construction, a world being terraformed over a time span of millennia by a galactic real estate corporation. Her partner, a moose named Whistle, missed the boat on the intelligence assessment, and is classed not as a person, but as a Mount. Destry considers him an equal and a close friend, but technically she owns him. He has been fitted with a neurolinguistic limiter, in keeping with his status, to stop him speaking freely.

The pair encounter a species that shouldn't be there, living under extreme conditions to hide from the corporation, the motives of which grow more sinister with every page. The rangers then need to rethink the systems they have been living with up to now: what is the ceiling on equality when everything is done according to one group's rules?

> **"Sci-fi is uniquely placed to examine a big moral question of our time: what do we owe non-humans in our care?"**

Science fiction is uniquely placed to examine a big moral question of our time: what do we owe the non-humans in our care? In the Anthropocene, we control the fates of many animals because we control their habitats, and some societies are starting to think it isn't OK to treat these animals inhumanely. So how do we enshrine this goal? Should animals be granted personhood?

> **Terraforming means creating human values as much as physical places**

This has long been suggested by moral philosophers like Peter Singer, who argues animals should be persons if they can experience self-awareness over time. But what then? Will that be enough, given how we treat other persons? Who grants personhood? And what relationship will it codify when rights seem to be contingent on human-like intelligence?

Granting such rights has been the assumption in sci-fi, from H. G. Wells's *The Island of Doctor Moreau* to David Brin's *Uplift* trilogy. Brin's books, in particular, assume that it is an unalloyed good to "uplift" other animals to intellectual parity with humans, that we will subsequently treat them as equals and that the animals will be happy to take part.

But Newitz sees that humans like to rig the game, that animals might come with their own grievances and questions, and that it will be hard to escape the inertia of hierarchies keeping us locked in status games.

*Terraformers* is packed with detail and filled with descriptions of meetings and meal prep – like a manual for running a commune. But that may be exactly what it is meant to be: a commune to uplift all creatures from the tyranny of human evaluation.

If Kim Stanley Robinson's *Red Mars* trilogy was a blueprint for how to terraform a planet, Newitz has described how one might build systems from the ground up that apportion value fairly, with air we can all breathe. ▮

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# Be your own hero

You can boost well-being and achieve your personal goals by taking control of your self-narrative, finds **David Robson**

EVERYONE knows what makes a good story. Our hero starts their journey as a flawed but relatable being with a personal goal. In scene after scene, they face challenges and setbacks that push them down new paths. By the end of the tale, they have prevailed and become a better person in the process. Just think of Jane Eyre, Luke Skywalker or Gilgamesh.

We love these plots in the novels we read, the films we watch and the video games we play. But the principles of a good story offer much more than entertainment. Recent research shows that the narratives we tell ourselves about our lives can powerfully shape our resilience to stress. People who generate tales of struggle and redemption from their own lives appear to have much better mental health. You could describe this as the flawed hero effect.

Better yet, psychologists have found that spinning our memories into a well-told life narrative, and viewing our future as an extension of this story, can help us achieve our aspirations for self-improvement. And if you want to turn over a new leaf, it helps to choose a significant date that signals the start of a new "chapter". Contrary to popular scepticism, resolutions made on 1 January are more effective for this reason. So, whether your goal is saving money, studying for exams, quitting smoking or getting fit, there is no better time to start. You just need to know how to harness the power of self-narrative to boost your willpower, improve your well-being and create a better you.

The original protagonist in the burgeoning field of narrative psychology is Dan McAdams at Northwestern University in Illinois. A humanities major for his undergraduate degree, he had always been drawn to the grand narratives of novelists like Leo Tolstoy. Then, when he switched to studying psychology, he began to think about the story we tell about ourselves and wondered whether this is, in fact, the essence of individual identity.

Previously, psychologists had seen identity as a combination of someone's values and beliefs, their goals and their social roles, with a particular emphasis on the ways they compared themselves with others. McAdams doesn't question the importance of these elements, but he proposes that a personal narrative, based on our autobiographical memories, binds them all together. It is our reflections on this story that give us a strong sense of who we are and, crucially, shape how we interpret current and future events. "An identity is supposed to integrate your life in time," he says. "It's something in your mind that puts together the different roles in your life and situates you in the world. And like every story, it has characters, it's got a plot and it's got themes that run through it."

McAdams formulated this idea, which he calls the life story model of identity, in the 1980s. Analysing people's recollections and questioning them about their sense of self, his work suggested that people's identities really are drawn from their life stories in this way. Over the past two decades, his hypothesis has attracted increasing attention from many other psychologists.

Much of the early research focused on the origins of our self-narratives. McAdams and others found that young children tend not to see their lives as a story made of interconnected events. Instead, their autobiographical memories are fragmentary. It is only in adolescence and early adulthood ›

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**A positive personal narrative could help motivate you to volunteer**

that most people start to engage in more sophisticated "autobiographical reasoning", which involves reappraising the meaning of our memories and slotting them together into a more coherent structure. "The cognitive operations that are required to create narrative in your life don't really come online until the teenage years," says McAdams. He describes this as transitioning from the role of "actor" to "author". As a result, for example, a typical 10-year-old is unlikely to see their parents' divorce as a turning point in their life, whereas a 15-year-old will tend to.

It has also become clear that the basic structure of our personal narrative resembles that of a book: we organise our life story into specific chapters representing important transitions in our identity. "You think of life in terms of periods: the time where I was in elementary school, the time where I lived in this house or this city or the time I was in this relationship," says Dorthe Kirkegaard Thomsen at Aarhus University, Denmark.

As research in the field progressed, it soon became apparent that people vary in their ability to create a personal narrative. By analysing people's accounts of important life events, researchers can judge the coherence of their stories – whether they have a definite chronology with obvious causality between one event and another. Such studies show that some people's stories are full of details, while those of others are much vaguer, with important knock-on effects for their well-being. People with more coherent narratives tend to have a stronger sense of identity and they feel their life has more meaning, direction and sense of purpose. Such people show greater overall life satisfaction too.

McAdams and his colleagues have also investigated the link between well-being and certain narrative themes. They discovered that agency – whether someone describes having had some control over events in their past – is an important predictor of mental health. "People who are depressed or overly anxious often describe their life narratives in a kind of non-agentic way," says McAdams. "They have the sense that 'I'm being pushed around by forces that I can't control'."

Another key theme is redemption, which involves finding some kind of positive meaning after stressful events. "People could talk about gaining knowledge or personal growth," says McAdams. His research shows that this is often missing for people with mental health conditions such as depression. "They create these stories that they've ruined everything or that they can't create positive relationships and that they are destined to live that out forever," he says.

## The power of redemption

Themes of redemption may be particularly important when we are trying to overcome a bad habit or addiction. One study asked new members of Alcoholics Anonymous to describe their last drink. Some gave straight factual descriptions, while others described a personal moment of realisation, leading to a positive change in themselves. One individual, for instance, described finding his strength again: "I feel like this obsession has been lifted from me again, and I need to see everything I did wrong last time to make it better this time." More than 80 per cent of the people telling a redemptive story remained sober over the following four months, compared

## Story time

**Creating a coherent narrative about your life can have huge benefits to your well-being (see main story), but children take years to develop this skill. Psychologist Elaine Reese at the University of Otago, New Zealand, has spent the past two decades examining the ways that parents' conversations with toddlers can help.**

**Recalling a trip to a natural history museum, a young child may say a single word, such as "bones". Many parents will simply let the conversation drop at this point, but Reese asked those in her study to pay attention to such cues and to follow them up with open-ended questions, encouraging their child to elaborate on the story. "That's really the key to the technique, getting them to give voice to their memories," says Reese. The parent should then affirm the child's answer, and build on it, as an active sign of their interest.**

**Reese found that parents given these guidelines were still applying the strategies a year later and that this improved the detail of the children's autobiographical memories compared with their peers. Astonishingly, these differences were still apparent in adolescence. When Reese interviewed the same children at age 15, she found they were better than others at telling coherent stories about possibly tricky turning points in their lives. "They were able to draw more meaning out of the difficult event," she says. This, in turn, was linked with better emotional well-being.**

FABRIZIO LENCI

with 44 per cent of those who didn't.

Such findings have led psychologists studying narrative psychology to wonder whether people can be taught to tell better stories about themselves – ones that would bring about positive personal growth.

A first inkling that this might be possible came in 2010. A team led by Sharon Danoff-Burg, then based at the University at Albany in New York, asked three groups of participants to complete questionnaires about their mental health, before spending 20 minutes writing about their past. Some were asked to give a factual description of a house they had once lived in. Others were encouraged to express their deepest thoughts and feelings. A third group wrote about a specific event and were told to focus on storytelling elements, such as the background to what occurred, the details of how it unfolded and the outcome. The essays of this last group showed greater narrative structure and coherence than the others and these people also experienced improvements in their mental health over the next month. A few people in the expressive writing group had naturally written in a narrative style too and, tellingly, the more coherent their stories, the better their subsequent well-being.

New research indicates that it is even possible to improve the storytelling skills of toddlers, with long-lasting benefits to their well-being (see "Story time", left). Meanwhile, multiple studies show the equally impressive benefits of simply writing down your self-narrative. Kirkegaard Thomsen, for example, found that this can boost self-esteem. In three separate studies of more than 400 participants in total, she and her colleagues asked people to write about specific life chapters before being questioned about their opinions of themselves, including their self-confidence. Participants reported more positive perceptions of themselves, compared with people who instead wrote about the lives of famous figures such as James Dean. "Thinking about narrative chapters gives you a stronger sense that you have value as a person," says Kirkegaard Thomsen. "And the writing process makes it feel substantial."

**"A narrative-bolstered sense of empowerment can improve your self-discipline"**

The good news for anyone trying to turn over a new leaf in 2023 is that this bolstered sense of empowerment can improve your self-discipline too. McAdams, working with Northwestern University colleagues Brady Jones and Mesmin Destin, asked 14 and 15-year-olds to write about a time when they had failed and a time when they had succeeded. Half of them were then given extra instructions to describe the ways they had made their success a reality (encouraging reflection on agency) and how the failure had changed them for the better (encouraging reflection on redemption). Eight weeks later, members of this group reported greater persistence in their schoolwork, and they had better grades. ›

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**Taking the plunge on 1 January will help you keep your resolutions**

As exciting as these results are, Kate McLean at Western Washington University in Washington state sounds a few notes of caution. Her first concern is that, hearing about the power of redemptive narrative, many people may feel compelled to find a positive spin on traumatic events. If they can't, they could end up feeling guilty about having somehow "failed", which will only exacerbate their distress. McLean says that Western culture – and particularly US culture – already pushes people to look for the silver lining behind every cloud. "That pressure can be really problematic," she says.

McLean also warns that the self-esteem boost that comes from focusing on our life narrative might sometimes undermine efforts at self-improvement. Working with Lauren Jennings, then also at Western Washington University, she gave participants false psychological feedback suggesting they were prejudiced. This led to a serious dip in their self-esteem. However, if they then wrote a story detailing a high point in their life, they quickly recovered from the uncomfortable feelings this produced and reverted to viewing themselves as tolerant people. "We can tell ourselves stories so that we don't need to think about something uncomfortable, or change our behaviour," says McLean.

## New Year, new you

Clearly, narrative interventions aren't a panacea. And when confronted with a harsh truth about ourselves, we would do far better to see that as a reason for change than simply discounting what we have learned. Nevertheless, if you are aspiring to self-improvement, you can use the findings about self-narrative to good effect – and the New Year is an ideal time to start.

Consider the work of Katy Milkman, who studies behavioural change at the University of Pennsylvania in Philadelphia. Inspired by research on narrative psychology, she examined whether we can use significant dates to signal the beginning of a new chapter in our lives – and if this, in turn, can motivate us to forge healthier habits. New Year's resolutions are the most obvious example of this principle in action, and polls suggest this temporal landmark is indeed a motivator: around a third of people manage to keep all their resolutions and half stick to at least some of their goals for the year. Milkman's findings indicate that the effect isn't limited to New Year: things like a birthday, a new academic term or moving to a new house can also inspire change. In one study, she and her colleagues found that simply labelling 20 March as "the start of spring" boosted people's motivations to adopt a new habit, such as increased gym attendance, on that date.

Milkman's team didn't check whether those good intentions translated into action, but a large field experiment, led by John Beshears at Harvard Business School, found that this strategy can bring real change. The team worked with four US universities to offer 6000 employees the chance to increase their savings with a new retirement plan. Some participants were given potential start dates that signalled a new beginning, such as their birthday, New Year's day or "the first day of spring", while others got less salient start dates, such as "in two months". It worked exactly as expected: nudging people to think about a new life chapter significantly increased the take-up of the programme.

> **"We can use significant dates to motivate us to forge healthier habits"**

Whether or not you plan to make any specific New Year's resolutions, the start of 2023 is the perfect opportunity to reflect on your life story – and to think about your future. Perhaps you will decide to take up journalling to help build a more coherent narrative of your past as a way of understanding your present. Or maybe you can look ahead to important moments in the coming months that will allow you to make a fresh start on some important goal.

Our lives may not be as dramatic as those of our favourite fictional characters. But by recognising ourselves as the hero at the centre of our own struggles, we can all, in a very literal sense, become the author of our own destiny and change ourselves for the better. ▮

David Robson is the author of *The Expectation Effect: How your mindset can transform your life*, out now in paperback

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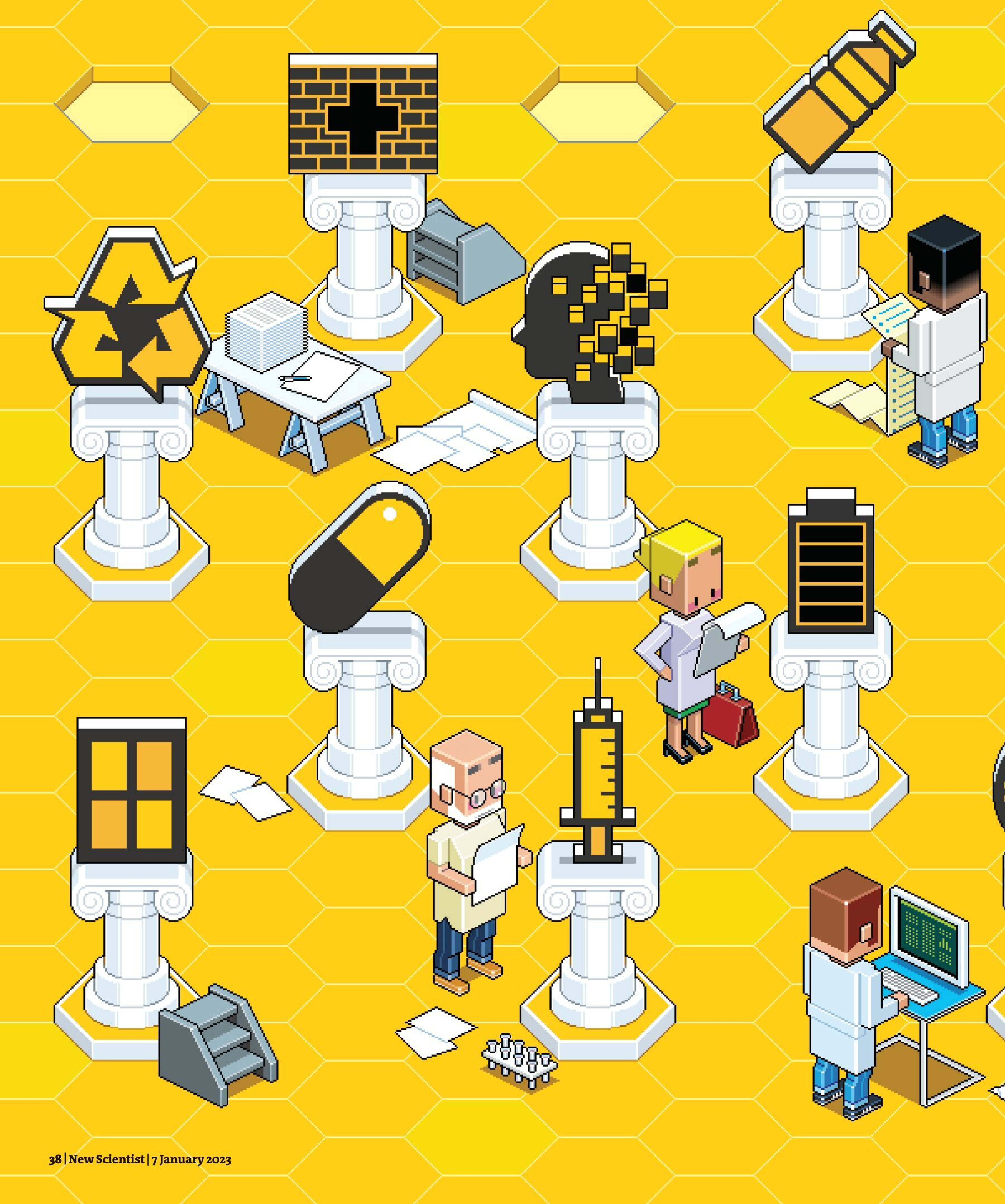

# How to save ourselves

Which innovations should we prioritise if we are to secure the future of humanity and the environment? **Vaclav Smil** has the answers

I HAVE never been a fan of science fiction. I am highly suspicious of any too-good-to-be-true claims about "epoch-making" discoveries. But I have also written extensively about the transformative impacts of inventions, from synthetic ammonia for fertiliser production and semiconductor devices in electronics to the 5-in-1 vaccine, which immunises against a range of diseases. What's more, it seems obvious to me that we need new fundamental advances like these to cope with the multitude of economic, social and environmental challenges we currently face. I address potential advances in my new book, *Invention and Innovation: A brief history of hype and failure*.

Identifying the top priorities for possible breakthroughs isn't easy, not least because there is so much room for improvement. Consider energy. Bill Gates has noted that: "Half the technology needed to get to zero emissions either doesn't exist yet or is too expensive for much of the world to afford." You could say the same about every scientific and technical category. Moreover, any list of the most desirable inventions is bound to be subjective. If you see mine as rather conservative, I plead guilty: there is no faster-than-light travel, no terraforming of other planets.

Instead, my top 12 innovations, which I set out here, cover a range of issues that we urgently need to address. They focus on areas that will have the biggest impact on human well-being and the environment and where there is already knowledge to build on. My wish list even includes three changes that all of us can get to work on right now (see "Bigger and better", page 40).

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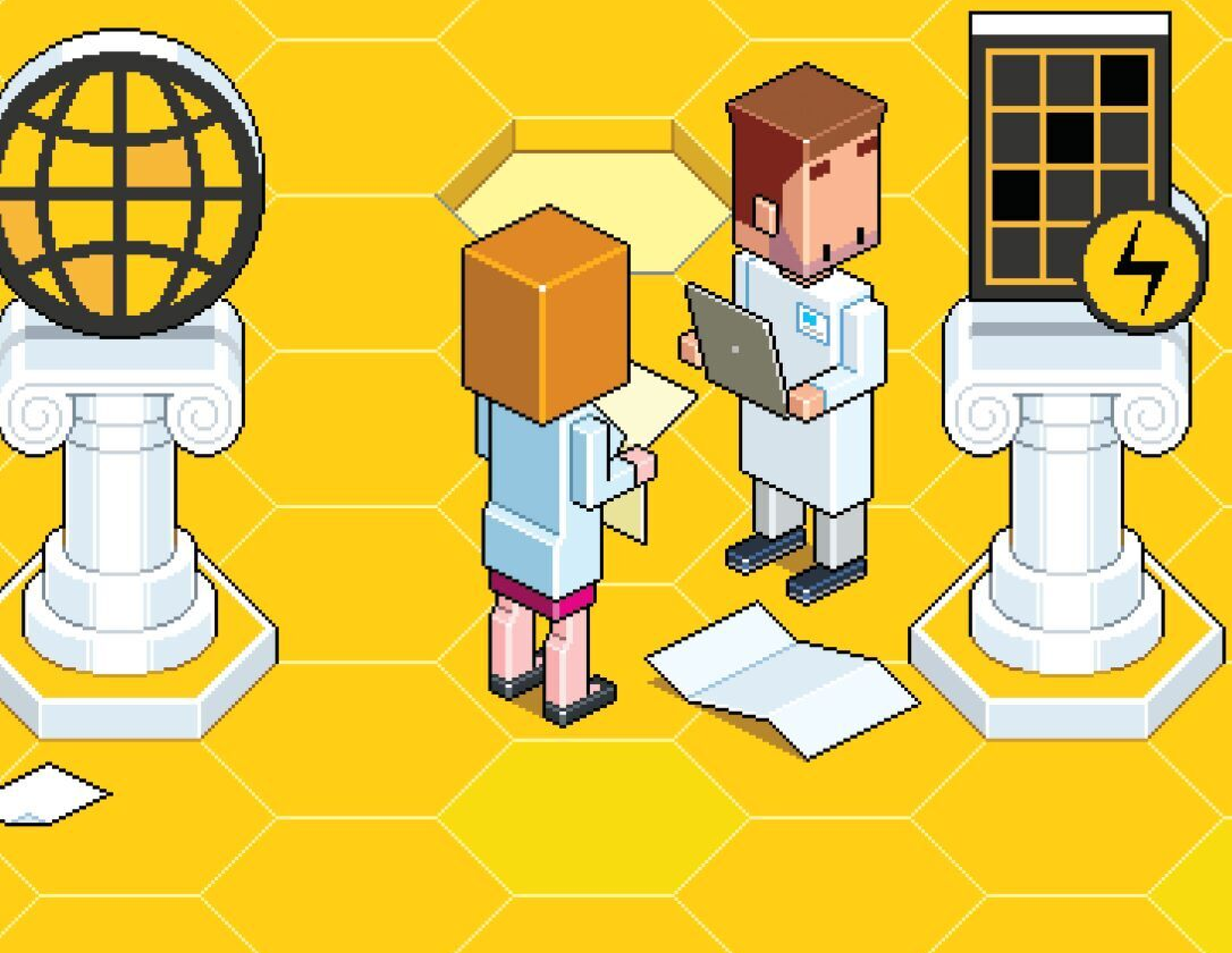

## A universal vaccine precursor

Humanity faces more risk from communicable diseases than ever. They can arise in tropical forests or in large cities, then spread rapidly around the world by global travel and transmit easily in overcrowded urban environments. We have been made painfully aware of this over the past three years by the coronavirus pandemic. It also highlighted the importance of vaccines – and the urgent need for better ones.

Vaccination has come a long way: it has eradicated smallpox and helped control many other infectious diseases, including polio, measles and tetanus. Today, there are several types of vaccine and we know how to employ them against a range of pathogens. Nevertheless, when a new disease arises, we must still develop a vaccine from scratch. And that takes time. We have seen the arrival of mRNA vaccines, which use the genetic material known as messenger RNA to tell our cells to produce a protein that teaches our bodies to recognise an invader. Speedy genetic sequencing is vital to the technology. The mRNA advance has drastically reduced the time it takes to invent new vaccines – from months or years to days. But even Pfizer/BioNTech's record-breaking covid-19 vaccine roll-out took nine months. That is plenty of time for an aggressive new pathogen to kill many millions of people.

Ideally, to reduce this delay, we would have an off-the-shelf, universal vaccine precursor that could be "activated" in the lab by a sample of a new viral or bacterial pathogen to create a vaccine that was safe, reliable and could be produced without using complex industrial techniques that are inaccessible to all but the largest pharmaceutical companies. So far, the closest we have come to this is research on "pan" vaccines that cover all viruses in a particular class, such as coronaviruses. In November 2022, researchers announced they had created a universal flu vaccine that › works on all 20 known subtypes of influenza A and B in mice. But what would a universal precursor look like and how could it be tuned to create any desired vaccine? For now, we just don't know.

## A cure for Alzheimer's

Since its creation in the 1930s, the US Food and Drug Administration (FDA) has approved more than 1800 treatments for human diseases. There are drugs that treat or even cure an impressive range of potentially fatal maladies, including various cancers, bacterial infections and high blood pressure. Others are designed to alleviate the symptoms of unpleasant but non-life-threatening conditions, from dermatitis and migraines to restless leg syndrome. Unfortunately, dementia – of which Alzheimer's disease is the most common form – isn't among the curable conditions. And, as populations age, this poses an ever-greater problem for humanity. Already, Alzheimer's affects about 2 per cent of the US population and some 44 million people worldwide. Dementia currently costs the world about 1 per cent of its GDP.

There are some drugs that provide temporary relief from Alzheimer's symptoms. For example, donepezil, galantamine and rivastigmine prevent the breakdown of acetylcholine, a chemical messenger in the brain important for alertness, memory, thought and judgement, while memantine regulates the activity of another neurotransmitter called glutamate. But these medications often have severe side effects. Moreover, they are unable to slow or halt progression of the disease.

Finding a cure for Alzheimer's is challenging because it is a complex and poorly understood condition. Hypotheses about what causes it range from inflammation to the misfolding of proteins in the brain. The FDA only approved the first drug to target a supposed underlying cause in 2021. Aducanumab decreases the amount of plaques of a protein called beta-amyloid in the brain, although in clinical trials it failed to clearly demonstrate any benefits on people's everyday functioning, thinking or memory. The following year came the announcement of the first Alzheimer's drug – lecanemab – that claimed to slow cognitive decline. However, its effectiveness is in dispute and, moreover, it has some severe side effects. By any standard, a cure for Alzheimer's must rank near the top of the most desirable scientific advances. Few other medical interventions would bring as much help to individuals, support to stricken families and relief to overstretched healthcare systems.

## Nitrogen-fixing cereals

As the human population passes 8 billion, ever-greater amounts of nitrogen-based fertilisers are being used to grow plants to feed us. In 2020, crops received 113 million tonnes of it, 40 per cent more than in 2000. However, as a result of evaporation, leaching, erosion and its conversion to nitrogen gas by soil microbes,

## Bigger and better

**We don't necessarily need new inventions to make big improvements for humanity and the planet. A few quick wins could come from doing what we already know, only better and on larger scales. Here (and continued on page 42) are three things we can do right now that would have huge impacts.**

### ELIMINATE MICRONUTRIENT DEFICIENCIES

Around a quarter of the world's population is anaemic due to a lack of dietary iron. In most countries of sub-Saharan Africa, the prevalence is between 40 and 50 per cent. About 250 million people don't have enough vitamin A, which can lead to blindness and reduced immunity. Iodine deficiency affects about 2 billion people. It increases infant mortality and can result in stunting and goitre. And zinc deficiency, which causes skin lesions and hair loss, affects at least 17 per cent of the global population. Yet measures such as providing vitamin and mineral supplements and fortifying oils and fats with vitamin A, flours with iron, and salt with iodine are inexpensive and very effective. Eliminating micronutrient deficiencies is perhaps the most rewarding development we could make immediately: only vaccination in childhood yields greater return on the relatively modest investment.

### FIT BETTER WINDOWS

Cutting energy demand is the best way to reduce humanity's carbon footprint without any new inventions. One obvious way to do this is by reducing the amount we waste. In only about half of the applied nitrogen ends up in crops – sometimes as little as 20 per cent. This loss is very unwelcome right now with fertiliser prices being so high. Worse still, it causes massive environmental damage, such as acid rain, the contamination of water by nitrates and the formation of oxygen-depleted "dead zones" in shallow coastal regions.

Unlike staple cereal crops, leguminous plants such as peas and beans require little or no nitrogen fertilisation. They get their nitrogen directly from symbiotic bacteria associated with their roots. The idea of conferring similar nitrogen-fixing abilities on grains, vegetables and other crops has been around for a century. It was even championed by Norman Borlaug, who won the 1970 Nobel peace prize for developing high-yielding crop varieties that required heavy applications of nitrogen. In his acceptance speech, Borlaug expressed a hope that, by the 1990s, humanity would have "green, vigorous, high-yielding fields of wheat, rice, maize, sorghums and millets, which are obtaining, free of expense, 100 kilograms of nitrogen per hectare from nodule-forming, nitrogen-fixing bacteria".

Since then, there has been some progress in identifying nitrogen-fixing genes and experimentally transferring them to non-leguminous plants. But nitrogen-fixing cereals remain a dream and nobody knows how long it will take to become reality.

## More efficient photosynthesis

Evolution has left plants with an inherently inefficient way of converting energy into biomass. Only around half of the solar radiation reaching a plant is usable in photosynthesis and that falls to 44 per cent after subtracting the reflected green light, leaving the blue-and-red part of the spectrum. More losses occur in the process of turning this light into chemical energy, so that just 4.5 per cent of solar energy is converted into carbohydrates. And that is a theoretical maximum. Limited supplies of water and nutrients mean that photosynthesis typically converts less than 1 per cent of incident solar radiation into biomass. Even a relatively small improvement would make a big difference in crop yields, which are currently stagnating or only increasing slowly.

Research in the past decade suggests three paths towards this goal. One is to improve the efficiency of rubisco, the enzyme that speeds up the process of synthesising new biomass. Another is to find genes that make roots more efficient at gathering water and nutrients and use synthetic engineering to incorporate these into plants. The third would build on the discovery of rice plants with higher yields, faster growth and more efficient use of nitrogen. We need more advances like these to substantially increase yields from crops if we are to adequately feed a human population that may well grow to 10 billion by 2050.

## Better batteries

If we are to replace a large share of fossil fuels with electricity, we must find better ways of storing it. Currently, the potential energy in pumped hydro projects account for more than 90 per cent of electricity storage worldwide. However, when it comes to electrifying transport, what we need are batteries that deliver more energy for their size – more watt-hours per litre (Wh/l).

In 1859, when Gaston Planté invented the lead-acid cell, it had an energy density of around 60 Wh/l. Today, hundreds of millions of such batteries are under the hoods of vehicles powered by internal combustion engines, and they deliver about 90 Wh/l. Modern nickel-cadmium batteries can store 150 Wh/l. But lithium-ion batteries – developed during the 1980s and used today to power electric cars as well as cellphones, laptops and other portable consumer electronics – are currently the best choice. And they have even more potential. The top commercial lithium-ion performer – used in millions of electric vehicles – is Panasonic's model 2170, with an energy density of 755 Wh/l. California's Amprius Technologies is developing lithium batteries that can store 1150 Wh/l, making them an order of magnitude more energy-dense than the best lead-acid storage.

Despite these improvements, the energy density of batteries remains far inferior to that in the liquid fuels that dominate all forms of transport: petrol rates at 9600 Wh/l,

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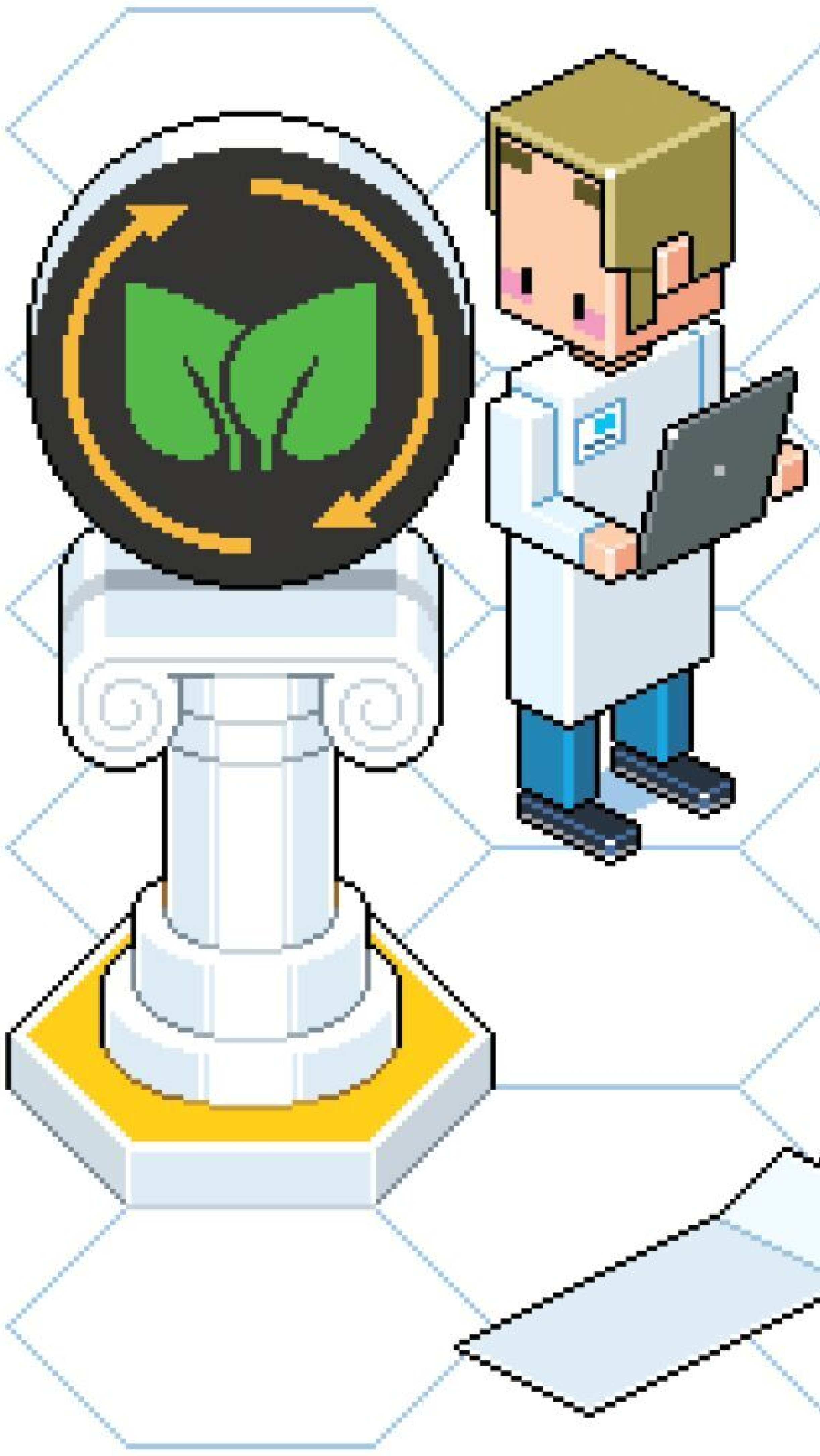
**"Dementia currently costs the world about 1 per cent of its GDP"**

high-income countries, buildings account for between 35 and 40 per cent of total energy demand – and windows are their most inefficient component. Double glazing reduces the heat loss of a single-glazed window by 50 per cent and triple glazing cuts another 50 per cent. Special coatings on glass and filling the spaces between panes with insulating argon cuts the overall loss by about 85 per cent compared with a single pane. Swapping out windows isn't cheap, but this technical fix is applicable to billions of windows worldwide. It would also have decades-long benefits: buildings typically have longer lifespans than cars (at around 12 years) and industrial processes (commonly from 20 to 30 years). Here is a massive opportunity to cut energy use, saving money and decarbonising at the same time.

**MAXIMISE RECYCLING**

We use huge amounts of energy and raw materials to produce a growing array of items, but we still recycle only a fraction of what is profitable – and even less of what would be desirable when all environmental costs are taken into consideration. Recycling rates are particularly low for plastic – just 9 per cent – half of which ends up in landfill. Less than 20 per cent of electronic waste is recycled, even though it contains more gold, silver, copper and rare-earth metals than any known mineral ores. Only about 60 per cent of paper is recycled. Globally, some three-quarters of aluminium is recycled, but national rates can be far lower: in the US, it is just 50 per cent. The benefits of recycling are well known, technical solutions are available and opportunities abound. There is no excuse. We should be doing far better.

aviation kerosene at 10,300 Wh/l and diesel fuel at 10,700 Wh/l. How fast could we narrow the gap? During the past 50 years, the highest energy density of mass-produced batteries has increased fivefold. If we can match that rate over the next 50 years, we would reach 3750 Wh/l. That would make the electrification of heavy road and maritime transport far easier than it is today, but it would still be insufficient for an electric Boeing 787. We need super-batteries, and the sooner the better.



## Self-cleaning, photovoltaic 'paint'

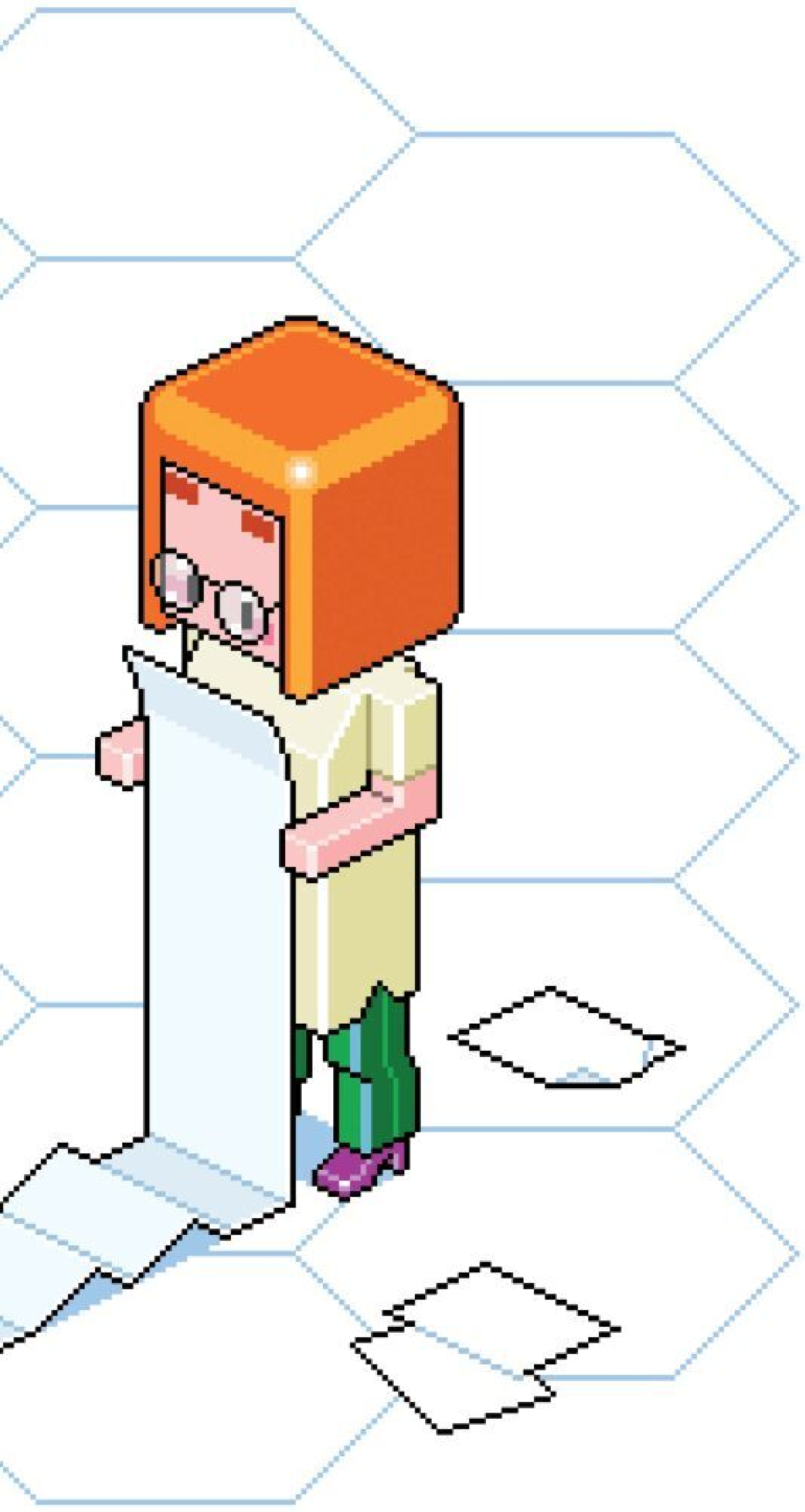
Solar is the best option for generating renewable electricity. Even if you don't consider wind turbines to be eyesores, they consume enormous amounts of materials – up to 400 tonnes per megawatt of installed capacity, which is more than 60 times as much as gas turbines. They also often require long-distance transmission to bring electricity from windy regions to big cities. In contrast, photovoltaic installations, whose semiconducting materials convert solar energy to electricity, use around 60 tonnes of material per megawatt of power and can be installed in any sunny location. Modern versions are also quite durable and maintain their performance for at least two decades, which is comparable with wind turbines.

So far, most new solar energy comes from large installations on unused land. Cities would be a better location. They already house more than half of humanity, will be home to some 70 per cent of people by 2050 and are by far the largest consumers of electricity. So, it would be a great boon to have photovoltaic coatings that could be applied, almost like paint, to any urban surface, connected to inverters located in individual buildings and fed into local grids. Of course, it would help if those coatings were also self-cleaning.

We have made some progress towards such surfaces. Solar cells can now be made from plastic and electricity-generating solar windows are on the market. Furthermore, glass-maker Pilkington produces self-cleaning windows, whose photo-catalytic and hydrophilic coatings react with sunlight to break down and loosen organic dirt. The next step will be to make these materials inexpensive and adaptable. Then, we can install them on a scale limited only by the size of our walls and windows.

## Reinforced concrete without cement or steel

The dominant material of modern civilisation is reinforced concrete. It comprises a mixture of cement, water and aggregates strengthened with steel rods. Cement, in turn, is commonly made from limestone, shells and chalk combined with shale, clay, slate, slag from blast furnaces, sand and iron ore. Global production of cement now surpasses 4 billion tonnes a year and this energy intensive process accounts for about 8 per cent of global carbon



“We need photovoltaic coatings that can be painted on to any surface”

emissions. Cement is mixed with water and aggregates – mostly sand – to make 14 billion tonnes of concrete, and this leads to depletion of river and beach sands – desert sand is a poor choice because its grains are rounded by wind erosion and so too smooth.

Concrete can be made without cement, by substituting fly ash or blast furnace slag, but the supply of these materials is limited and will decline still further as coal combustion decreases and new iron-smelting techniques are adopted. In 2021, Japanese researchers announced they had found a way to make concrete without cement, by directly bonding sand particles (including those from deserts) using a simple reaction in alcohol with a catalyst. Efforts to substitute the steel rods in reinforced concrete with a greener alternative are more advanced. German engineers have constructed the world’s first building made from concrete reinforced with carbon fibres. However, it was only a demonstration project and the carbon concrete was about 20 times as expensive as the standard product. In the future, the biggest demand for concrete will be from low-income countries, so we need to combine the two technologies in a material that is cheaper than today’s reinforced concrete and then scale up production globally.

## Greener plastics

The worldwide production of plastics is approaching 400 million tonnes a year. Meanwhile, our efforts to reduce their harmful environmental impacts are pitiful. The benefit of banning single-use shopping bags, for example, is dwarfed by the growth in other single-use plastics such as blister packs and the ubiquitous clamshells used in food packaging. Meanwhile, only a small proportion of all the plastic we discard is recycled or incinerated. In high-income countries, most ends up in landfill. In low-income countries, especially in Asia, a lot enters the ocean, where macro and microplastics are accumulating in surface waters and even in the deepest trenches.

Biodegradable alternatives, derived from crops or produced by microorganisms, are available. However, they aren’t widely used, accounting for less than 1 per cent of all production. Besides, plastics perform so many different functions that we need to invent a variety of green alternatives that are both cheap and strong. To eliminate competition with food production, these shouldn’t be made from crop-derived compounds, but from readily available organic waste, microbes and inorganic material. This remains an enormous challenge – with equally enormous rewards.

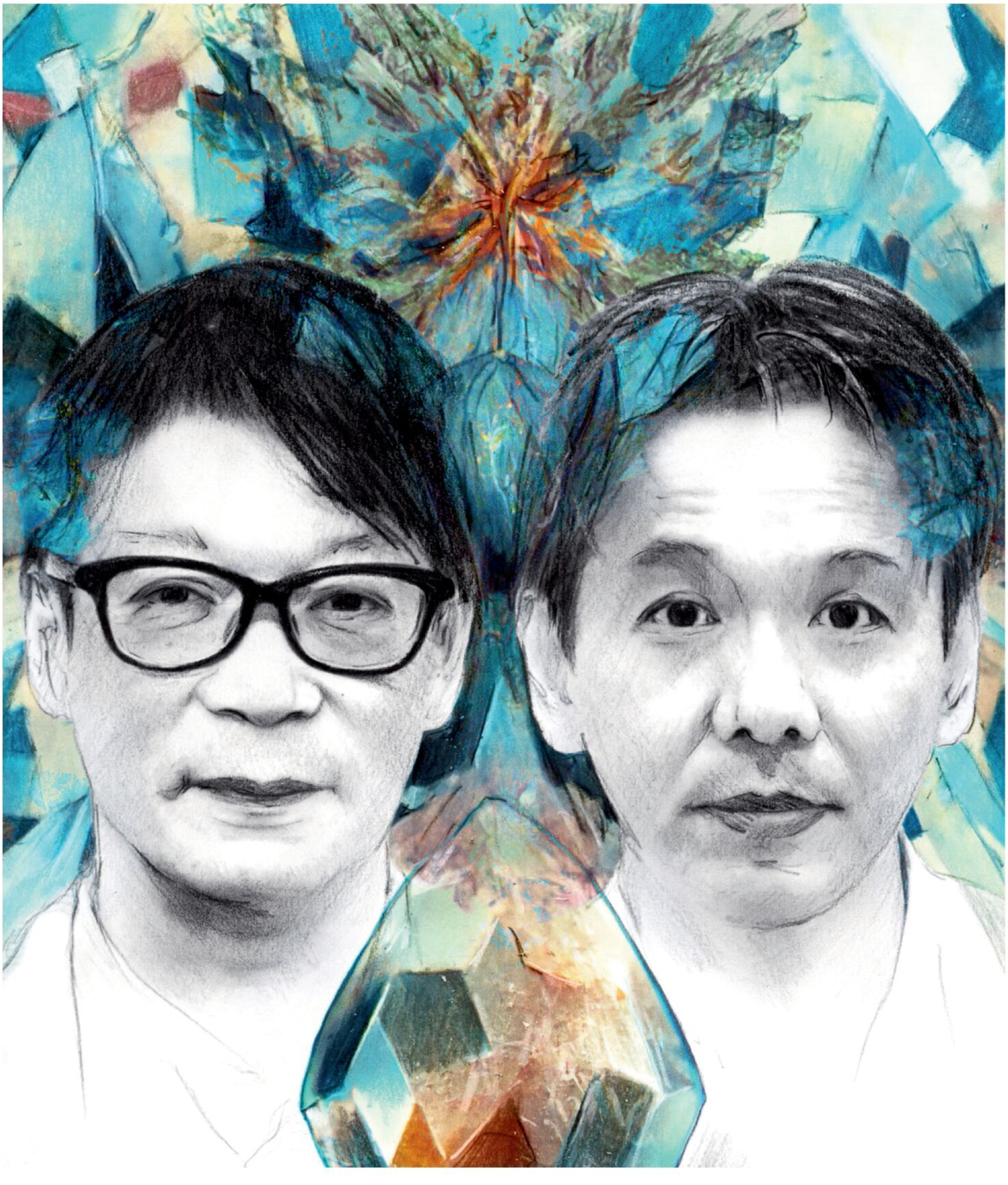
## A planetary sunshade

The last item on my list is a bit of a wildcard. It is a controversial idea, but if we fail to make better progress at controlling greenhouse gas emissions, we may have to resort to blocking some of the incoming radiation from the sun. Doing that in space by using a giant shield or parasol would be a less intrusive option than injecting radiation-absorbing aerosols into the stratosphere. The sunshield idea has been around for decades, but is still far beyond our capacities to translate into reality.

Forming a sunshade capable of deflecting between 1 and 2 per cent of sunlight would involve either deploying billions of small, light autonomous sail-craft or a massive barrier, which might take the form of a disc, a very light lens or a thin wire mesh. This barrier would need to be parked about 1.5 million kilometres away, at the point between the sun and Earth where their gravitational forces cancel out so that an object can stay in position.

There are two gigantic problems with this plan. First, it would mean launching something in the order of 10 million tonnes of equipment into space. Even with optimistic assumptions, that would cost many trillions of dollars. Second, even if technically possible, the project would require a binding global consensus and legal framework before it could go ahead. The likelihood of such an agreement would increase if the design were adjustable and controllable. Nevertheless, this innovation seems far less likely to happen any time soon than the other items on my wish list. ∎

Vaclav Smil is a distinguished professor emeritus at the University of Manitoba, Canada. *Invention and Innovation* is published this month



NABIL NEZZAR

# Crystal masters

**Takashi Taniguchi** and **Kenji Watanabe** are the unsung heroes of a two-dimensional materials revolution. Anna Demming asks them about their unusual path to fame as the world's best crystal growers

FOR years, Takashi Taniguchi and Kenji Watanabe were like most other physicists, labouring away relatively unknown to the wider world. The pair studied crystals in their lab at the National Institute for Materials Science near Tokyo, Japan.

Then, almost overnight, they hit the big time. They had been growing a cubic crystal form of boron nitride that has the same three-dimensional structure as diamond. One day, out of curiosity, they investigated another type of boron nitride crystal that sometimes grew as a by-product in their lab – a flat, two-dimensional form.

With it, they inadvertently struck gold. That's because, around this time, another 2D substance was starting to make waves. Graphene, formed of a sheet of carbon just a single atom thick, was dubbed a "wonder material" due to it being a great conductor, stronger than diamond and lighter than paper. An influx of graphene research began, trying to make the most of this stuff.

The problem was, to study graphene, you need something very flat with just the right properties on which to mount the wafer thin sheets. The solution, it turned out, was the very by-product crystals Taniguchi (on the left in the artwork) and Watanabe had been investigating.

Their high-purity 2D boron nitride crystals are, by wide consensus, the world's best. Today, what was once a waste material is supplied to everyone in the graphene field to enable groundbreaking research and the two scientists are co-authors of more than 1000 studies. They told *New Scientist* how they honed their craft, found themselves at the centre of a materials revolution and became the world's most in-demand crystal growers.

**Anna Demming: Let's start with the basics. What is a crystal?**

**Kenji Watanabe:** A crystal is a solid where the atoms are arranged in a repeating pattern. This affects how the electrons behave, which can lead to interesting electronic and optical effects.

**What were the first crystals you studied?**

**Takashi Taniguchi:** I started out working on making diamond. Diamond is not only a gem, but it is also a very hard material and a semiconductor – something that only conducts electricity if the electrons [in it] have enough energy to "switch on". Diamond has a wide bandgap – the minimum amount of energy needed for electrons to move through the material and create a current. This kind of behaviour is useful for devices, so companies all over the world are synthesising diamond, not just for jewellery, but for semiconductors.

**How did you go from diamond to what you are now known for, boron nitride?**

**TT:** Diamond is made of carbon, but next to carbon on the periodic table is boron on one side and nitrogen on the other. This means that boron and nitrogen, when put together, combine to make a similar structure to carbon, called boron nitride. I realised that while there were many research papers reporting on diamond, there was not so much on boron nitride, so there was a lot of space for further study.

**KW:** I had been studying the properties of semiconductors for high-power electronics. Boron nitride and diamond looked promising, but it was difficult to find large crystals of these materials.

**What makes a good crystal?**

**TT:** Diamond should be colourless. But man-made diamond [using high-pressure techniques] is always yellow. This is because there are nitrogen atoms in it. It's the same situation with boron nitride: if we want high-quality boron nitride, we need to remove the impurities, such as carbon and oxygen. So high quality means high purity.

**How did you hone your crystal-growing skills?**

**TT:** We learned a lot about growing cubic boron nitride from diamond synthesis. Graphite, loosely bound layers of carbon arranged in a hexagonal crystal pattern, converts to diamond with the right chemicals and high pressure. The same thing happens for boron nitride.

We started with hexagonal boron nitride, which is commercially available as a powder, and using a hydraulic press, a very big one, applied around 30,000 tonnes of pressure. We needed to find the right solvents to

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dissolve the hexagonal boron nitride and then create cubic boron nitride crystals. Once we did, it took a long time to grow the crystal – about five days. I tried many materials by trial and error and finally found putting barium in the solvent was very useful. This was the key.

**Today, the crystals you work on most of the time aren't cubic, but arranged in a flat, hexagonal pattern. What made you switch your attention?**
**TT:** Originally, this was sort of a by-product. When we grew the cubic boron nitride, hexagonal boron nitride was also produced, only much higher purity and with a larger crystal size than the commercially available starting powder.
**KW:** I became curious because, at the time, there weren't many articles reporting the bandgap and the luminescent nature of hexagonal boron nitride.

**How did that lead to wider attention on your crystals?**
**TT:** We published some papers about hexagonal boron nitride and its luminescence, and on our lab homepage, we had a picture of our crystals. They weren't large, maybe 1 millimetre in length, but that's how other people found out we were making these crystals. If Kenji had not discovered this [luminescent] aspect of hexagonal boron nitride, maybe none of this would have happened.

**At that point, graphene had recently been discovered. Why was this so important to your work?**
**TT:** Graphene is a single-layered material. Because of this, the big question at the time was what could we put it on to study it? This was a big issue for the 2D materials community because an atomic monolayer like graphene is very sensitive. If you put it on something that is not smooth, it is easily affected.

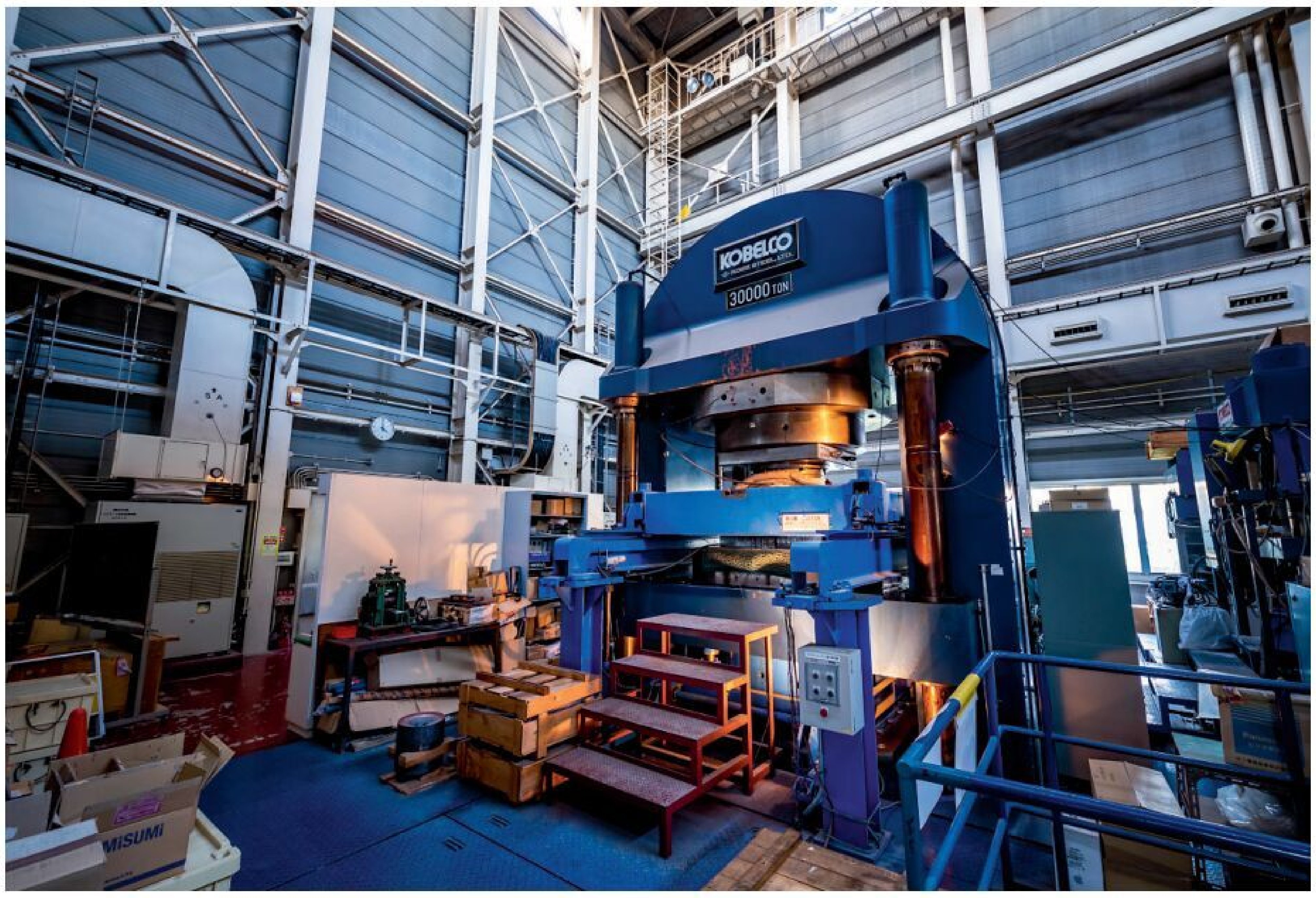
Hexagonal boron nitride is a wide bandgap material, so you can put graphene on it and it will not be affected, since the surface of the crystal is atomically flat and there is no electrical leakage. It was already a well-known material, but high-quality crystals were hard to come by.

CHRIS J RATCLIFFE/AFP VIA GETTY IMAGES

"I could not have imagined the demand we received"

After we had published our results on hexagonal boron nitride, Changgu Lee, a postdoc at the time at Columbia University in New York, contacted me. He asked us to supply one of our crystals because he wanted to measure a mechanical property of graphene on it.

**What happened next?**
**TT:** At that time, no one knew whether it was possible to combine two kinds of atomic layer. Lee published his report. And then, a year or so later, there were two other young guys at Columbia who wanted to use our crystals as a substrate, so we sent crystals to then PhD student Andrea Young – now a professor with the University of California, Santa Barbara – and Cory Dean – then a staff postdoc and now professor at Columbia University. When they placed graphene on the crystals, it looked very comfortable, there were no dangling bonds, atoms without a bonding partner, which



NIMS

**Cubic boron nitride has a crystal structure like diamond (left). It can be created from a powder using 30,000 tonnes of pressure from a hydraulic press (above)**

would have an electrical and chemical effect on another adjacent crystal. It was amazing. They reported this at a conference in 2010. That was the break.

**Were you surprised by the demand?**
**TT:** As a crystal grower, I was happy to learn that our crystals were somehow useful for the scientific community, though I could not imagine the demand we received. Our crystals were not large, still only 1 millimetre or so – they looked almost rubbish compared to other large crystals. But people working in 2D materials figured out how to work with them and the field grew up based on studies of materials with similar dimensions.

**Have the crystals you grow changed over the years?**
**TT:** The size is the same, there hasn't been much progress from my side in that respect. Even 20 years since we first made the crystals, it is still just 1 millimetre. But, for instance, initially our crystals had, say, 10 parts per million levels for carbon [impurities], now it is 10 parts per billion.

**Is it difficult deciding who to send crystals to or are you able to say yes to everyone?**
**TT:** I try to say yes to everyone. One important thing is that our institution is a government learning institution, so our export control office makes some careful judgements with respect to potential collaborators.

**Do you think the demand for these materials will continue?**
**TT:** At the beginning of 2010, when people started asking for our crystals, Andrea Young said, "You've become a very busy guy!" I supposed that might go on for two or three years and then calm down, but now it has been 10 or 15 years.

Year by year, there are new findings in graphene research. Things like twistronics, the idea that if you layer two sheets of graphene on top of each other with a twist in the orientation, new properties appear. The activity in the field is amazing. But how much longer? I am not in a position to say.

I think the idea of using hexagonal boron nitride crystal for 2D material systems will continue, but not only with our crystals. There are some younger researchers looking at new ways of growing hexagonal boron nitride crystals, with a method called large area deposition. I look forward to their success.

**What is that technique?**
**KW:** Large area deposition is where atoms are deposited on a surface from a vapour or liquid, for instance by chemical reactions. It is extremely difficult to obtain hexagonal boron nitride from large area deposition with a similar high quality to that of crystals grown under high pressure.
**TT:** There are already some papers on growing hexagonal boron nitride in this way, but we have to wait, we shouldn't rush them. I believe, in time, they will be successful.

**Are you teaching younger researchers your techniques?**
**TT:** One of the problems with our institution is age: the young people here are still over 40 years old. I would like to have some young people join. The number of students taking a doctoral course is getting smaller and I am quite worried about that.

**When you both retire, what will happen to the field if nobody takes over?**
**TT:** We have been open about how to make the barium solvent we use to create the high-quality crystals, it's not a secret. It's all in the open, either through a patent or a journal paper. I don't know why there are no companies making them yet. Probably, it wouldn't make any money! ▮

Anna Demming is a features editor at *New Scientist*

# The back pages

**Puzzles**
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***Almost* the last word**
If cells get renewed, how much of the old me remains? p50

**Tom Gauld for *New Scientist***
A cartoonist's take on the world p51

**Feedback**
Hospital dogs and the mathematical study of broken sticks p52

**Twisteddoodles for *New Scientist***
Picturing the lighter side of life p52

## Stargazing at home

# A stellar year ahead

It is time to put key astronomical dates for 2023 into your diary and hope for clear skies. Here is what **Abigail Beall** is looking forward to

Abigail Beall is a features editor at *New Scientist* and author of *The Art of Urban Astronomy* @abbybeall

### What you need

**Access to astronomy software such as Stellarium (optional)**

STARGAZING doesn't always go to plan. Even with the best of intentions, equipment and preparation, when it comes down to it, clouds can stop play. But knowing ahead of time when specific events are happening means that at least you will never be in the dark as to what is going on. That is why, at the start of each year, I make time to go through my calendar and pop in a few dates of upcoming astronomical spectacles I want to see.

One of the best ways to plan a stargazing session, whether it is for a specific event or just to look at the wonders of the night sky, is to use astronomy software. Regular readers of this column will know I am a fan of Stellarium, a free program you can use in a web browser or download as a desktop version. It has some advanced options for filtering to find targets, is easy to use and you can plug in your exact location and when you want to stargaze for any point in the future.

The first dates I will be putting into my diary this year are when the planets and the moon will be looking particularly stunning. On 23 January, the crescent moon will be next to Venus and Saturn in the sky, just after sunset. A month later, on 22 February, a sliver of the crescent moon will be right next to Jupiter, with Venus not far away. Then, on 1 March, Jupiter and Venus will pass by each other within half a degree – about the size of the full moon in the sky or the width of your thumb if you hold it at arm's length. These arrangements will all be visible from anywhere in the world.

LOVEMUSHROOM/SHUTTERSTOCK

Skywatchers in the southern hemisphere will be treated to a rare hybrid total solar eclipse on 20 April. This kind of eclipse happens when the moon blocks the whole of the sun's face in some parts of the world, but when viewed from some other places, it appears to be annular, which means a ring of light is visible around the moon's shadow.

Only people in the western parts of Australia and southern Indonesia will see the total eclipse. For those in the wider area, including Hawaii and Papua New Guinea, the eclipse will be annular.

There will be a lunar eclipse visible from most of Europe, Asia and Australasia on 5 and 6 May. A solar eclipse that will be annular for all viewers can be seen from parts of North and South America on 14 October. Finally, the fourth eclipse of 2023 will be a partial lunar one, visible from most of the world except western parts of the Americas, on 28 and 29 October.

There are dates that crop up around the same time every year, including meteor showers. On that front, the Lyrid meteors peak on 22 and 23 April, the Perseids on 12 and 13 August and the Geminids on 13 and 14 December, perfectly timed with a new moon. Join me in popping those dates in your diary, and wishing for clear skies. ▮

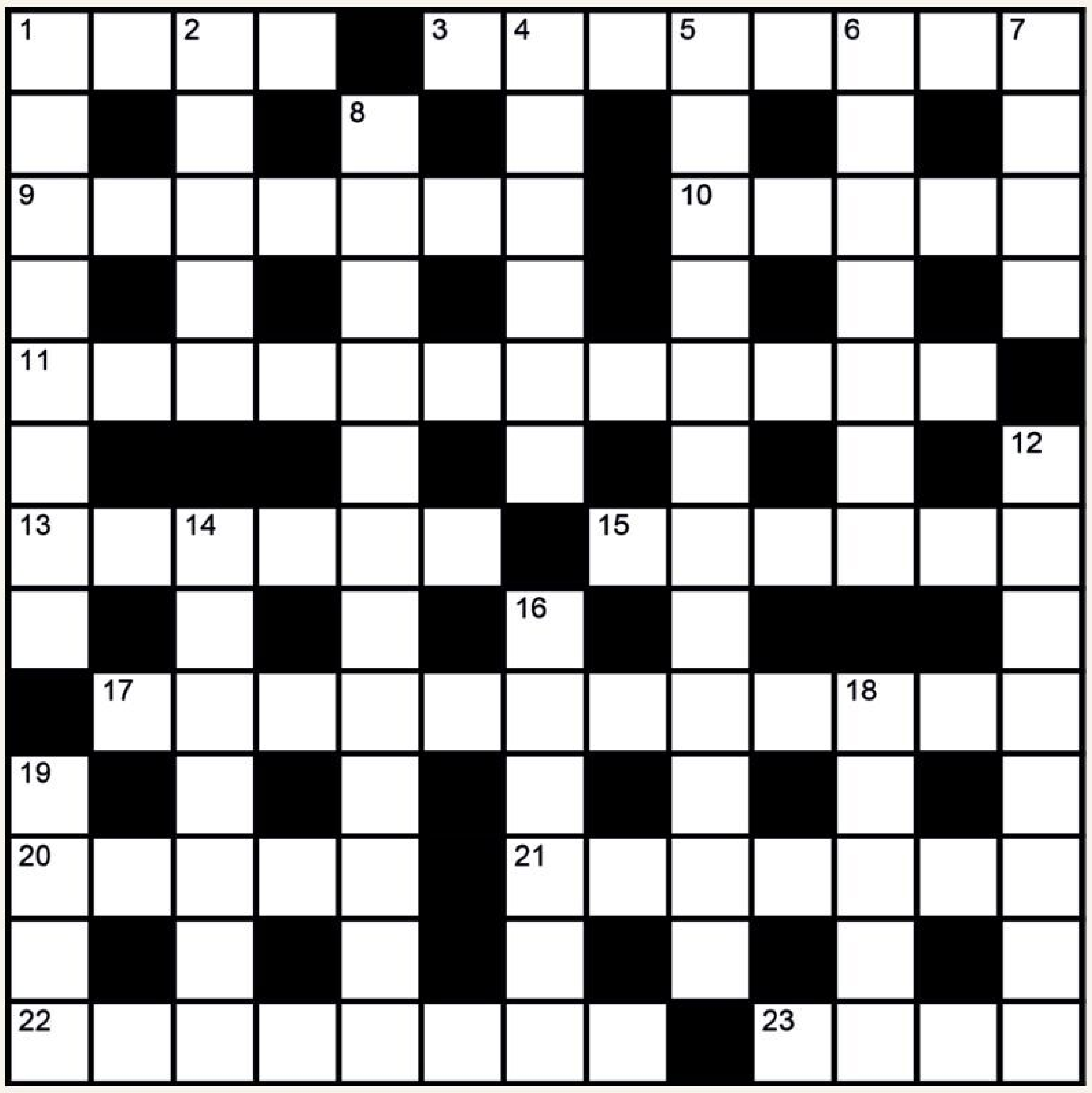
**These articles are posted each week at newscientist.com/maker**

*Stargazing at home appears every four weeks. Share your stargazing successes with us on Twitter and Instagram @newscientist, using the hashtag #NewScientistStargazing*

### Next week

The science of gardening

## Cryptic crossword #100 *Set by Wingding*



**Scribble zone**

Answers and the next quick crossword next week

**ACROSS**

**1** Neurological symptom to do with hearing left out (4)
**3** Period when sci-art is vandalised (8)
**9** Leaders of expedition need great polar explorer to draw attention (7)
**10** One enters diplomacy without speaking (5)
**11** Periodic visitor wrecked homely castle (7,5)
**13** Mountain range where tango may ensue? (6)
**15** Stick together carbon and oxygen in this place (6)
**17** Single-celled organisms addressed to dictator, given time (12)
**20** Mineral containing 25 per cent of charcoal pigment (5)
**21** Weak, I am walking with cane (7)
**22** University students embraced by friends on vacation before first period (4,4)
**23** Plant initially tall, grass cut short (4)

**DOWN**

**1** Meat ground with extremely heavy schist stone (8)
**2** Set up the Spanish star (5)
**4** Withstand hysteresis, though not entirely (6)
**5** Swarming Martians? Cool, great (12)
**6** Release classified information on energy (7)
**7** Refer to location out loud (4)
**8** Perhaps Turing and his colleagues treated deer with sore back (4,8)
**12** Walk around walls of Eton before English first period (8)
**14** Important chapel renovated with nothing inside (7)
**16** Japanese ruler and North Korean leader rising above turmoil (6)
**18** Wheat makes some of them merry (5)
**19** Carnivore diverted stream (4)

**Our crosswords are now solvable online**
newscientist.com/crosswords

## Quick quiz #183
*set by Bethan Ackerley*

**1** Which of these dinosaurs wasn't a theropod: *Tyrannosaurus*, *Giganotosaurus* or *Argentinosaurus*?

**2** Arrector pili muscles are attached to which structures in the body?

**3** An exceptionally bright meteor that explodes in the atmosphere before reaching the ground is known as what?

**4** Which British chemist discovered the element thallium?

**5** In what year was the Watt steam engine first introduced?

*Answers on page 51*

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## Puzzle
*set by Howard Williams*
### #203 Multiple magic

**This magic square has been known since ancient times. Each row, column and diagonal of three numbers adds to the same magic constant, 15.**

| | | |
|---|---|---|
| 6 | 1 | 8 |
| 7 | 5 | 3 |
| 2 | 9 | 4 |

**There is, however, a different type of 3×3 magic square, in which every row, column and diagonal can be multiplied together to produce the same number. There are plenty of ways to do this, but if every number in the square has to be a different, positive whole number, then the smallest example has a magic constant of 4096.**

**Which numbers go where in the square?**

*Solution next week*

## Original me

**I am 65. Assuming that I still weigh what I did at 25 (I wish!), what percentage of material from 40 years ago remains as part of me today?**

***@Nik_Henville** via Twitter*
While the "average" cell in our bodies lasts between seven and 10 years, the range is from 4 to 8 hours for immune cells called granulocytes to a full human lifetime for some neurons.

But percentage-wise, not a lot of your 25-year-old self remains.

***James Stone***
*Great Hucklow, Derbyshire, UK*
Maybe there is no need to worry about how much of the biological material from your youth is retained in your 65-year-old body.

Neurons in the hippocampus (a brain region vital for memory) are replaced at the rate of 1.75 per cent each year in adults. A naive calculation, assuming each neuron gets replaced only once, predicts that the entire hippocampus would be replaced after about 57 years.

> "You shouldn't worry about how much of the biological material from your youth is retained in your 65-year-old body"

If this applies to other brain structures, then it implies that an 80-year-old retains no neurons from their 20-year-old brain. Despite this, an 80-year-old can recall events from their youth.

So it isn't the preservation of material, but the preservation of information, that matters.

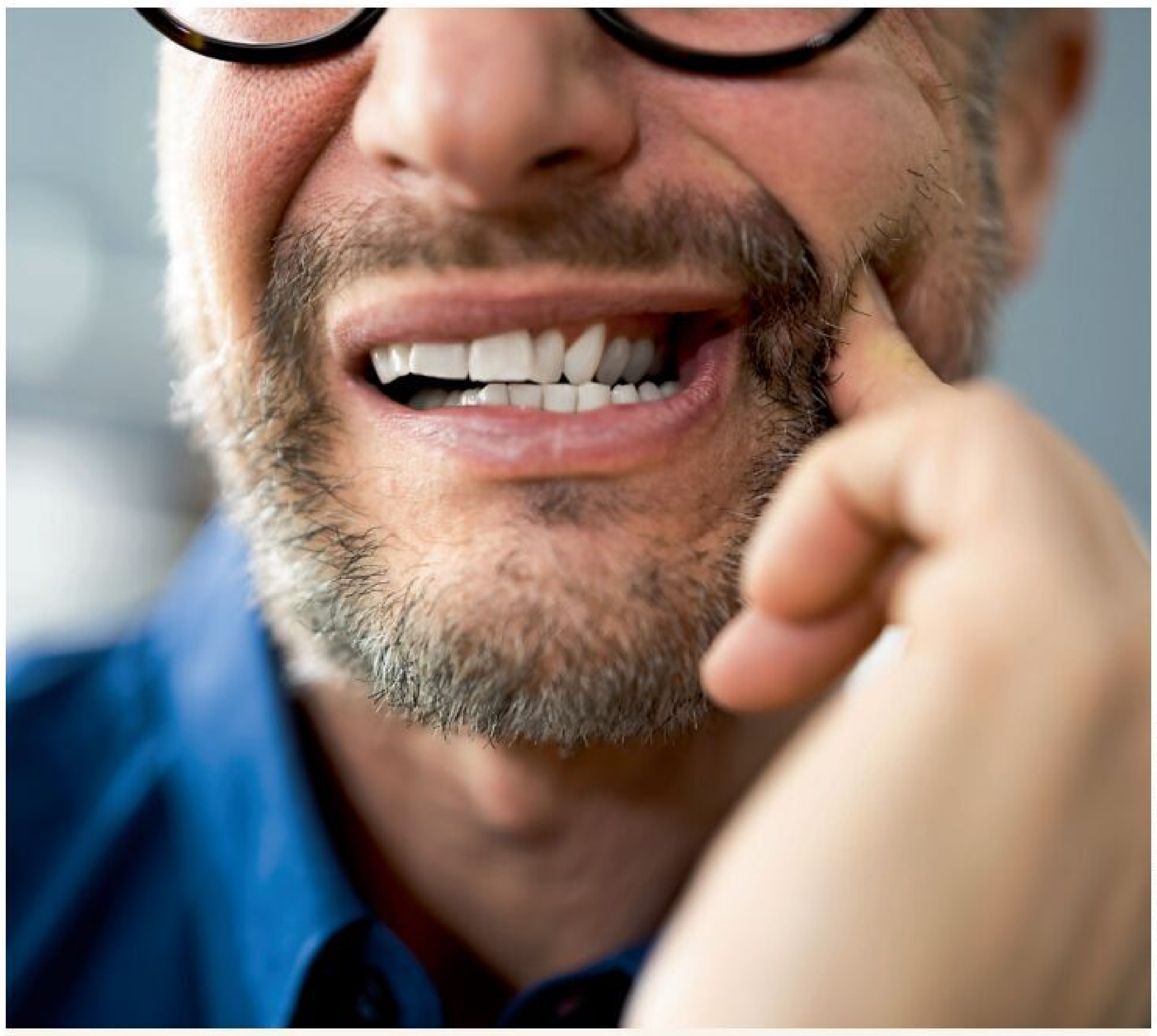
***John Peterson,***
*via Facebook*
What remains? Your teeth and your memories.

***Guy Cox***
*Sydney, Australia*
Your teeth remain, for a start. The enamel doesn't grow once formed and has no repair mechanism. Plus, a few cells of the body, such as spinal neurons, aren't replaced, so you have the original cells there.

However, some cells – such as those in skin and hair, as well as red blood cells – are continually replaced, so none of these will be the same ones 40 years later.

Even long-lived cells are metabolically active, with a turnover of material taking place in them, so the actual atoms in the cells are most unlikely to have been there for 40 years.

***Ian Sanderson***
*via Facebook*
It depends on how you define "me". If "me" is your physical body, not much. If "me" is your personality, most of it.


ANDREY_POPOV/SHUTTERSTOCK

What on Earth is the point of having nerve endings in our teeth?

### This week's new questions

**Painful bite** **Why do we have nerve endings in our teeth? They seem to serve no useful purpose.** ***Bruno Cappelli**, Melbourne, Australia*

**Shout it out** **When doing strenuous exercise such as weightlifting, it seems to help to call out the number of repetitions. Why?** ***Catherine de Lange**, London, UK*

## Spider freefall

**Do spiders survive if thrown from a height out of a window?**

***Hillary Shaw***
*Newport, Shropshire, UK*
In simple terms, an object's speed when falling through air depends on its shape and weight. For us, the highest, or terminal, velocity when falling near Earth's surface is about 200 kilometres per hour, but for a cat it is nearer 100 km/h and for a squirrel about 40 km/h.

Spiders vary in size and weight, but assuming that a spider weighs about 3 milligrams and has a cross-sectional area of around 100 square millimetres, it will reach a terminal velocity of around 0.7 metres per second, which is a slow human walking pace. The spider can probably withstand hitting the ground at this speed, while grass and leaves may cushion its impact.

However, it may emit some web that can act as a parachute, and this, together with its non-aerodynamic shape, means that it won't reach its terminal velocity anyway.

*[Ed – to be on the safe side, why not release spiders onto the window sill instead of flinging them out?]*

***Colin Oatway***
*Wokingham, Berkshire, UK*
The picture that accompanied this question when it was first posed (21 November) showed a pinktoe tarantula, *Avicularia avicularia*. Tarantulas aren't true spiders (one difference is that true spiders have six silk-producing spinnerets, whereas tarantulas only have two).

There are two types of tarantula: arboreal (tree dwelling) and terrestrial (ground dwelling). For the tree-dwelling types, any fall from even a metre or so onto a soft surface can be fatal. This is because the impact can split the abdomen, resulting in massive blood loss.

As a consequence, keepers tend to keep tarantulas in containers with a low ceiling, and filled with lots of earth, so that if the tarantula does climb to the top and fall, there is a good chance that the impact won't damage the abdomen too much.

I don't know as much about true spiders, but they can travel long distances by spinning out a web thread to catch the wind, a process called ballooning. Some spiders have been found ballooning more than 3 kilometres up in the atmosphere. Due to their low weight compared with body surface area, and the thread acting as a parachute, a true spider should survive a fall. However, if it is a type of house spider, it may not survive outside regardless of any issues with falling.

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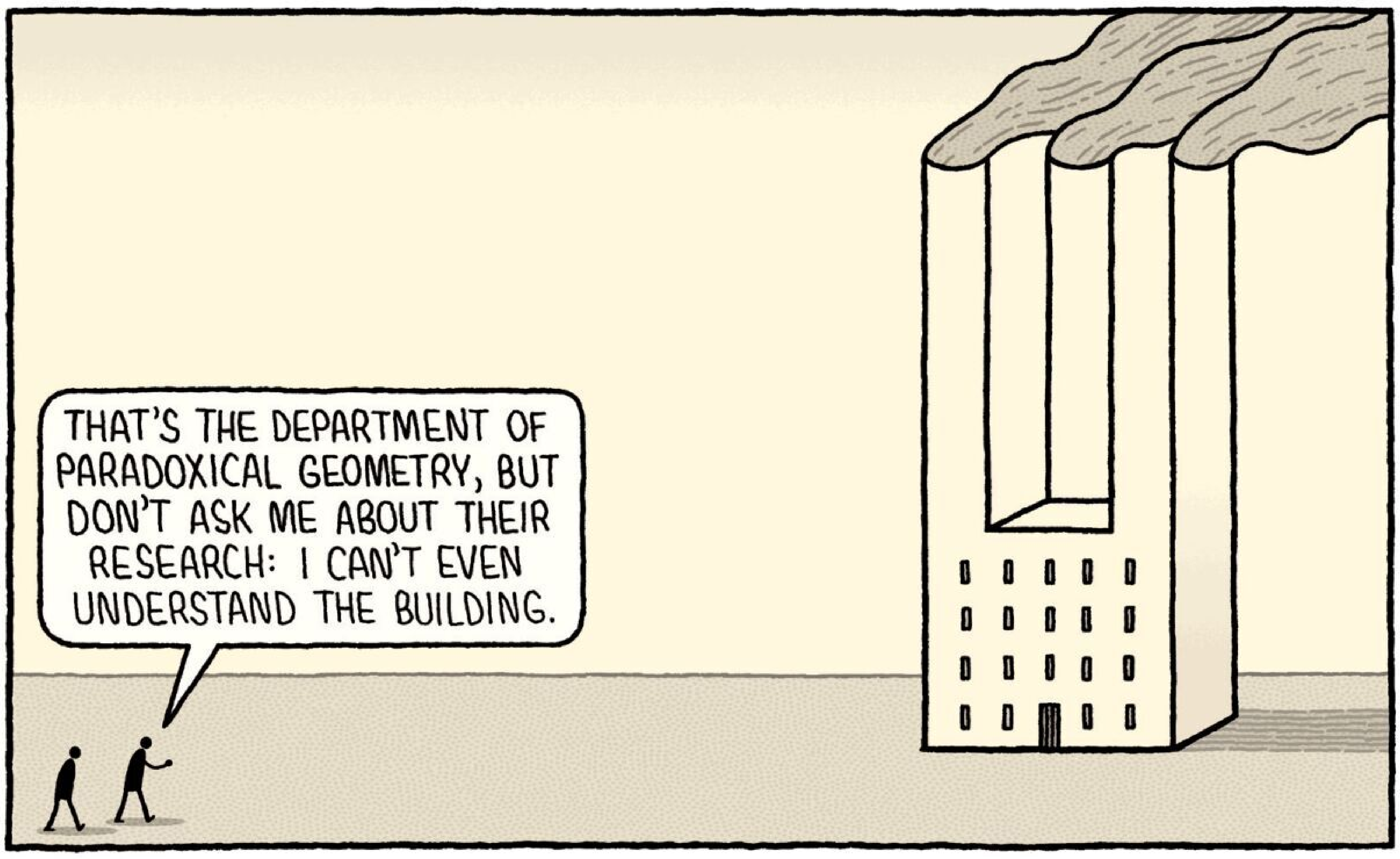
## Tom Gauld
*for New Scientist*


THAT'S THE DEPARTMENT OF PARADOXICAL GEOMETRY, BUT DON'T ASK ME ABOUT THEIR RESEARCH: I CAN'T EVEN UNDERSTAND THE BUILDING.

*Lachlan Jones*
*Brisbane, Australia*
This question reminded me of an occasion when I found a big huntsman spider in a mop bucket. I banged out the bucket over a balcony rail and the spider floated off in the breeze on a silken thread.

> **"A spider thrown from a window probably wouldn't reach terminal velocity due to its shape and silk parachute"**

## Speedy light

**I am at the rear wall of my spaceship travelling at the speed of light. I switch on my flashlight. Will the light reach the front wall? (continued)**

*Dave Rowsell*
*Swansea, UK*
This is pretty much the same question that Albert Einstein posed over a century ago when he asked himself what it would be like to travel alongside a light wave. In this case, he imagined travelling in a superfast tram at the speed of light, c.

With that in mind, I felt that some of the previous answers fell short, as they considered the scenario of travelling at a tiny fraction less than c and hence avoided the real issue: what would it be like to travel at the speed of light, not just close to it.

The difference is very important. As we move towards c, we approach the mathematical limits of the equations of special relativity. This is where maths takes us to both zero and infinity – never happy places in physics.

At c, conclusions emerge that run counter to our common sense. Space shrinks right down to zero. There is no space. Neither is there any time. This tells us that, from the viewpoint of light, there is no space-time, and therefore no such thing as "travelling". For light, everything is instantaneous, and there is no such thing as "here to there" or "then and now". It would be impossible for Einstein to run alongside light, like we could drive alongside one particular carriage of a train. His thought experiment was a misconception.

However, from our point of view, as conscious beings living in the environment of space-time, light takes time to get from A to B. So how do we square these two seemingly opposite views?

Our view of the universe clearly needs to be thought out anew. In a way, it is a shame we are asking the same question that Einstein did and, worse, that we are still settling for incomplete answers.

We still don't really question what we mean by reality, yet there could be so much to gain by doing so. Surely it is time to accept imagination as a key part of our scientific endeavour, and start applying it seriously and on a broad scale. Changing how we approach relativity and its limits might offer new clues to reconciling relativity and quantum mechanics. And who knows, it might also shed some light on the "hard problem" of consciousness? ▮

## Answers

### Quick quiz #183
*Answers*

**1** *Argentinosaurus*, which was a sauropod
**2** Hair follicles. Their contraction causes goose bumps
**3** A bolide
**4** William Crookes
**5** 1776

### Quick crossword #123 *Answers*

**ACROSS 7** Come to, **8** Thallium, **9** Varicose, **10** Earwax, **11** Morepork, **12** Oxygen, **13** *Time Bandits*, **18** Hyssop, **20** Nerve gas, **22** Icarus, **23** Gasworks, **24** Brown rat, **25** Croton

**DOWN 1** Nonagon, **2** Beriberi, **3** Bonobo, **4** Cane toad, **5** Blu-ray, **6** Pupates, **8** *The Sky at Night*, **14** Exposure, **15** Theropod, **16** Synchro, **17** Backhoe, **19** Screws, **21** Resect

### #202 The dating game
*Solution*

$22\div(9+\sqrt{(\sqrt{16})})=2$

$\sqrt{(22-9-\sqrt{16})}=3$

$22-(9\times\sqrt{(\sqrt{16})})=4$

$\sqrt{(22+\sqrt{(\sqrt{(9^\wedge\sqrt{(\sqrt{16})})})})}=5$

$(22-\sqrt{16})\div\sqrt{9}=6$

$\sqrt{(22+\sqrt{9})}+\sqrt{(\sqrt{16})}=7$

$(22+\sqrt{(\sqrt{16})})\div\sqrt{9}=8$

$22-9-\sqrt{16}=9$

$\sqrt{(22+\sqrt{9})}\times\sqrt{(\sqrt{16})}=10$

## A dogged presence

**Dogs should be kept out of human (that is, non-veterinary) hospitals – or, depending on circumstances, welcomed into them. Research papers make the case one way and another.**

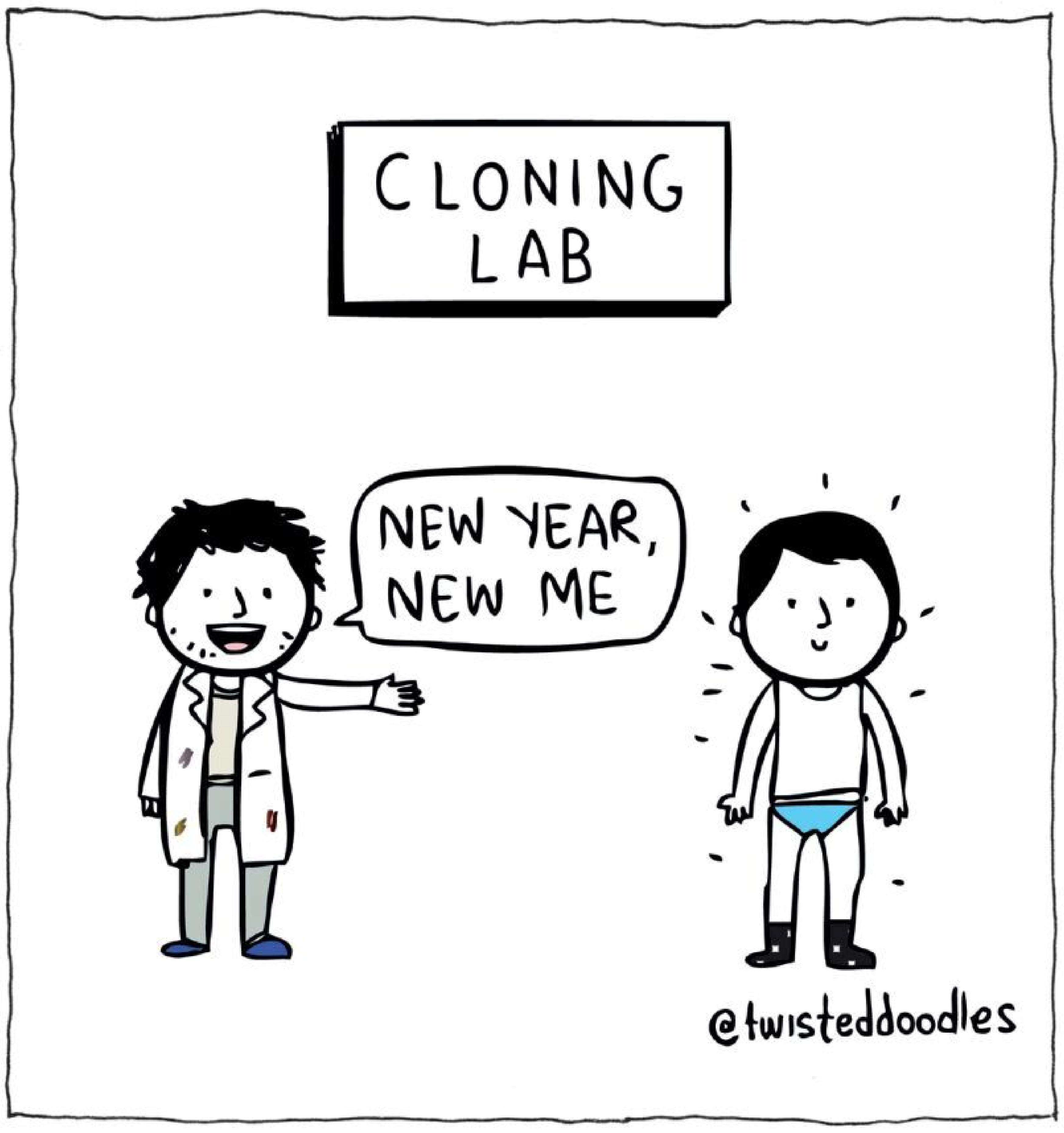
**"Towards dog-free hospital campuses in India", published in the *Indian Journal of Medical Research*, nods to hospitals that are, or might be, visited by stray dogs. These are also known in the literature by the old sobriquet "unbridled dogs", the technical term "free-ranging dogs" and the zippy nickname FRDs.**

**The report dishes delicious gossip about them: "Apart from rabies, FRDs are reported to transmit several zoonotic diseases… with incidents of dogs being on hospital beds and in ward areas, biting, obstruction of pedestrians (patients), barking and instances of grievous injuries even resulting in death." The study suggests creating "No Free-Roaming Dog Zones".**

**Researchers in Indiana, meanwhile, offered anxious hospital patients a visitation by (mostly bridled) therapy dogs. Their study, "Controlled clinical trial of canine therapy versus usual care to reduce patient anxiety in the emergency department", reports that the dogs seemed to render the patients "significantly" less anxious and that fewer people in the group who met therapy dogs needed pain medication than in a control group.**

**In the Netherlands, a study of "the contamination of assistance dogs' paws and their users' shoe soles in relation to admittance to hospitals" found that the levels of Enterobacteriaceae and *Clostridium difficile* bacteria on those paws and shoe soles were, in their word, "comparable". "Thus," they say, "hygiene measures to reduce any contamination due to dog paws do not seem necessary."**

## Twisteddoodles *for New Scientist*



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## Unpleasant polygons

What can you do with a broken stick? The question fascinates mathematicians, well, some of them. Lumberjacks, too – again, some of them. One difference between mathematicians, some of them, and lumberjacks, most of them, is that mathematicians publish a lot of academic papers. (In long-ago days, when lumberjacks roamed free in the world's forests, they supplied virtually all of the paper for those mathematicians' papers. The two groups are no longer so professionally entwined.)

A study, "On the probability of forming polygons from a broken stick", examines what is possible after you have broken a stick into pieces of random lengths. If you then pick – also at random – three of those pieces, can you lay them on the ground to form a triangle? Will four make a quadrilateral? Five a pentagon? Six a hexagon? And so on.

Author William Verreault at Laval University in Quebec, Canada, warns that you had better define the problem carefully. If you don't, then "the probabilities one seeks in a broken stick problem seem nearly impossible to calculate".

But if luck is with you – if you can form polygons – some of them may displease you. This puzzling phenomenon has been studied. It can approach what used to be called dark places of the soul. Johann Schneider, Krum Krumov, Ludmilla Andrejeva and Elka Kibarova went there, in 1993. Their study, called "Authoritarian attitudes and aesthetic preferences: A Bulgarian replication", used simple tests to probe the psyches of 173 university students in Bulgaria.

A study by Schneider eight years earlier had reported that German students – if those students were by nature conservative – perceived there to be "significant differences [in] pleasantness between polygons of low and high complexity". The Bulgarian study found no similar authoritarian/polygon-pleasantness perception distinction by conservative-natured students in Bulgaria. Nobody has yet explained why.

## The shape of things

**While many people work with explicit shapes, other people focus on shapelessness.**

**Tanya Behrisch at Simon Fraser University in Canada writes about the soundness of shapeless listening in "Shapeless listening to the more-than-human world: Coherence, complexity, mattering, indifference". Shapeless listening, says Behrisch, is a "contemplative practice of attending without seeking to understand". Her paper appears in *Cultural Studies Critical Methodologies*.**

**Behrisch is blunt about shapelessness: "Through direct encounters with the more-than-human world (MTHW) I encounter otherness. Practices of oil painting, slowing down, shapeless listening, and gazing afford distinct ways of seeing that resist comprehension, naming, or control."**

**Ryangmi Lee, Boyeon An and Eunjin Jun tell how to tame a different kind of shapelessness. They published a how-to report in the *Journal of the Korean Society of Clothing and Textiles*. The report, "Conservation treatment and the development of a relics filling pad to maintain the shape of a doctor's coat worn by Seo Jae-pil, the National Registered Cultural Heritage No. 607", is a guide for museum conservators who want to preserve the shape of clothing items entrusted to their institutions.**

**The paper documents a specific achievement that can now be an inspirational example: "A doctor's coat worn by Seo Jae-pil… was conserved with wet cleaning to remove thick wrinkles and brown stains that had been present for a long time."** ▮

*Marc Abrahams*

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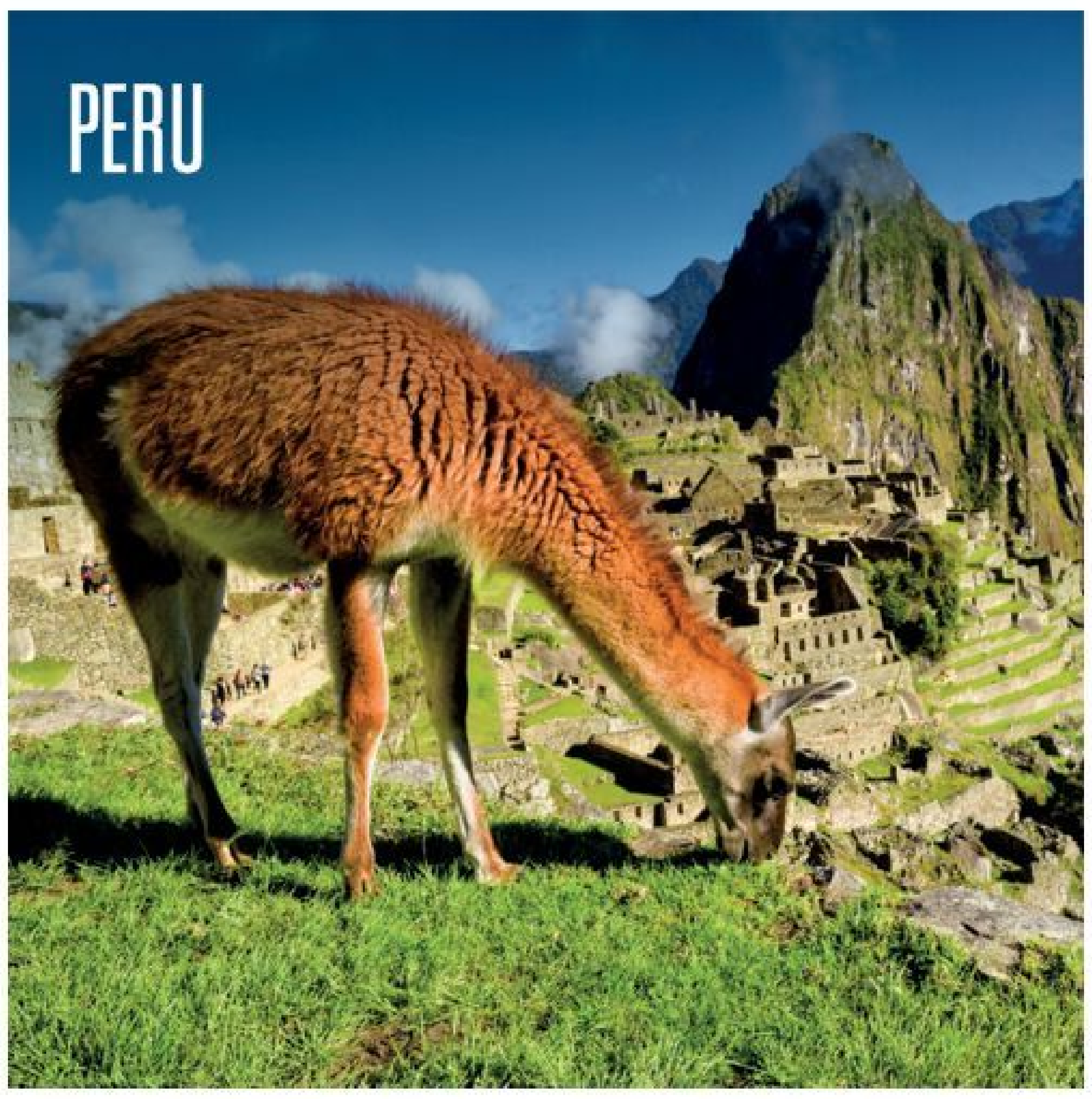

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## Nobel's Stockholm: Celebrating science through space and time: Sweden

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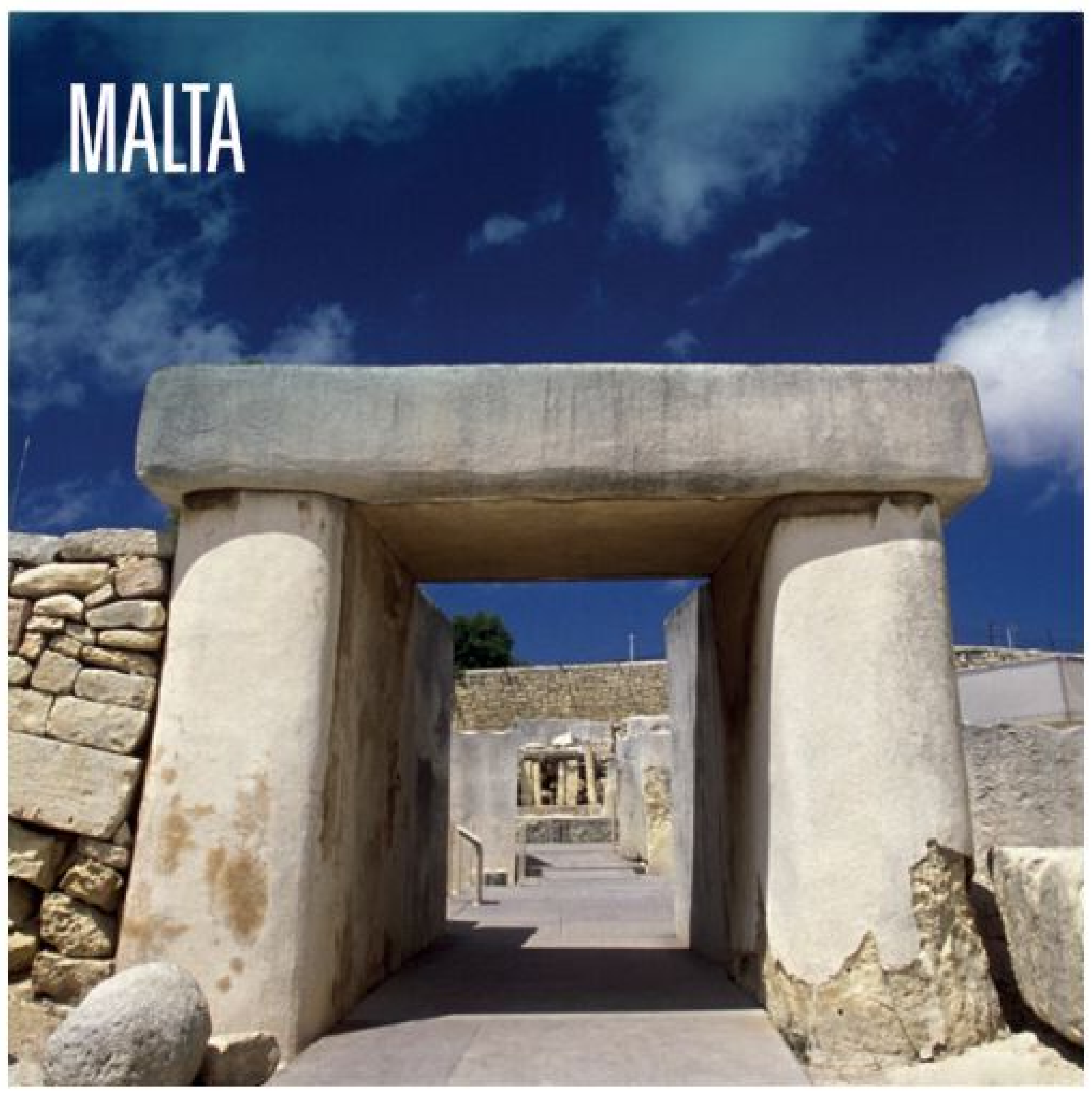
## Tiger conservation safari: India

**2 November 2023 | 10 days**

Visit the reserves of Pench and Tadoba in search of the Bengal tiger, staying in award-winning lodges and immersing yourself in jungle life. Explore the parks by jeep, bike and on foot accompanied throughout by experienced naturalist and conservationist Kartikeya Singh.



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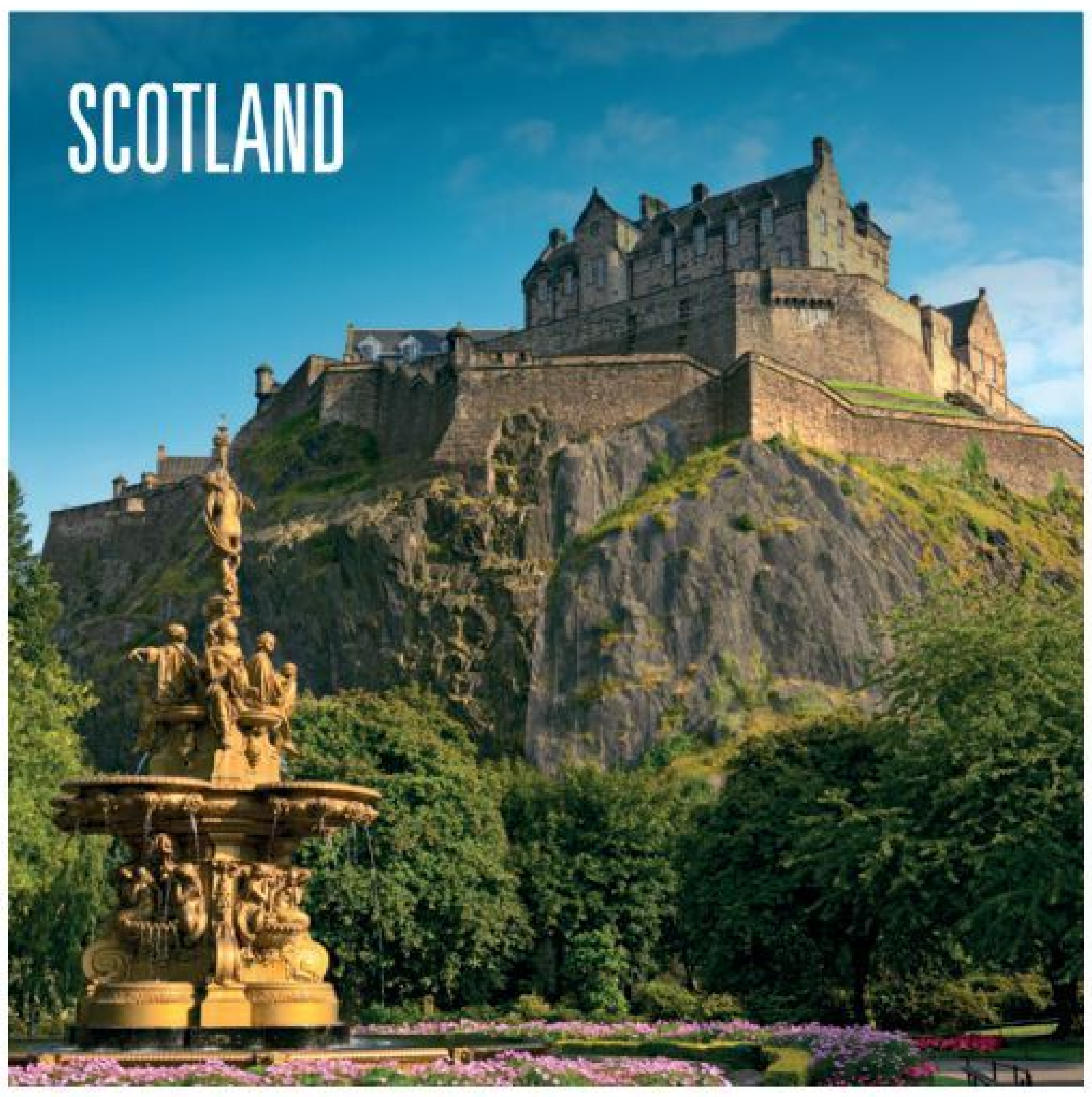

## The science history of Scotland: The enlightenment and beyond

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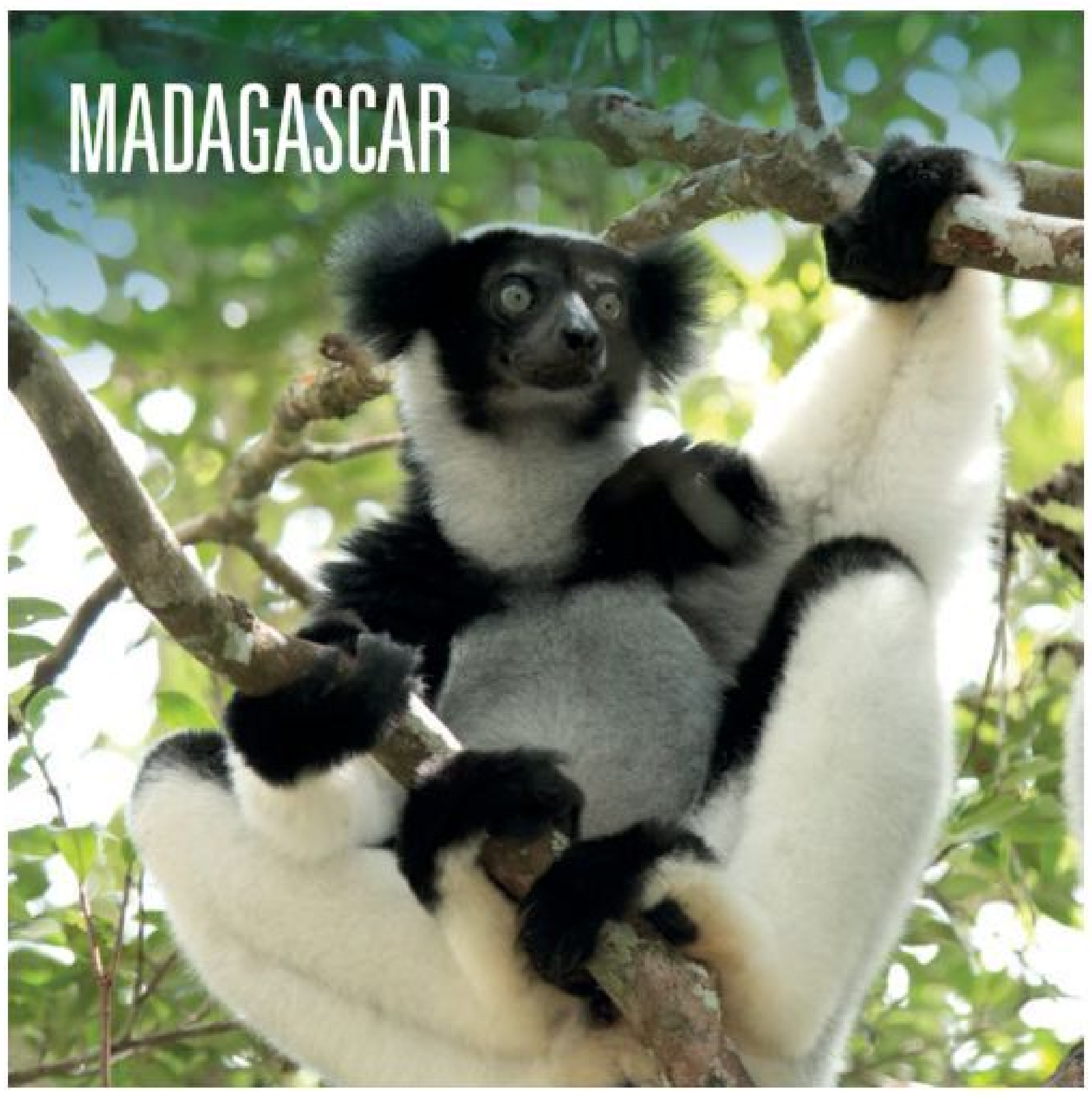

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**22 June 2023 | 10 days**

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## Darwin's Galapagos with Jo Ruxton MBE: Ecuador

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Tour the Galapagos Islands by boat as Charles Darwin did, taking an exclusive yacht. Galapagos sea lions, marine iguanas, blue footed boobies, giant tortoises, sally lightfoot crabs and green sea turtles are just a few of the animals you may see on this fascinating archipelago.

## Geology, dinosaurs and the Rocky mountains: USA

**16 July 2023 | 7 days**

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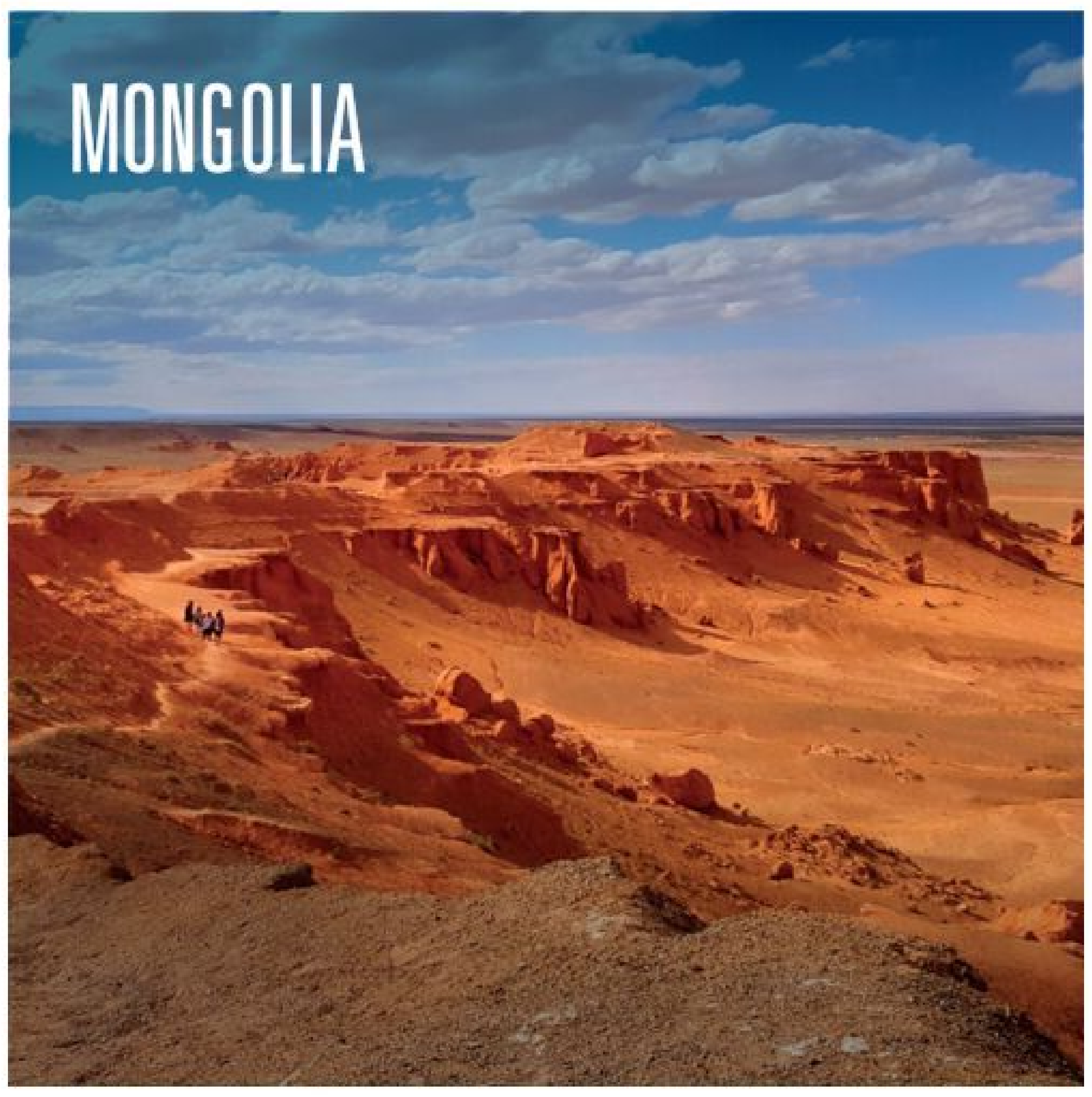

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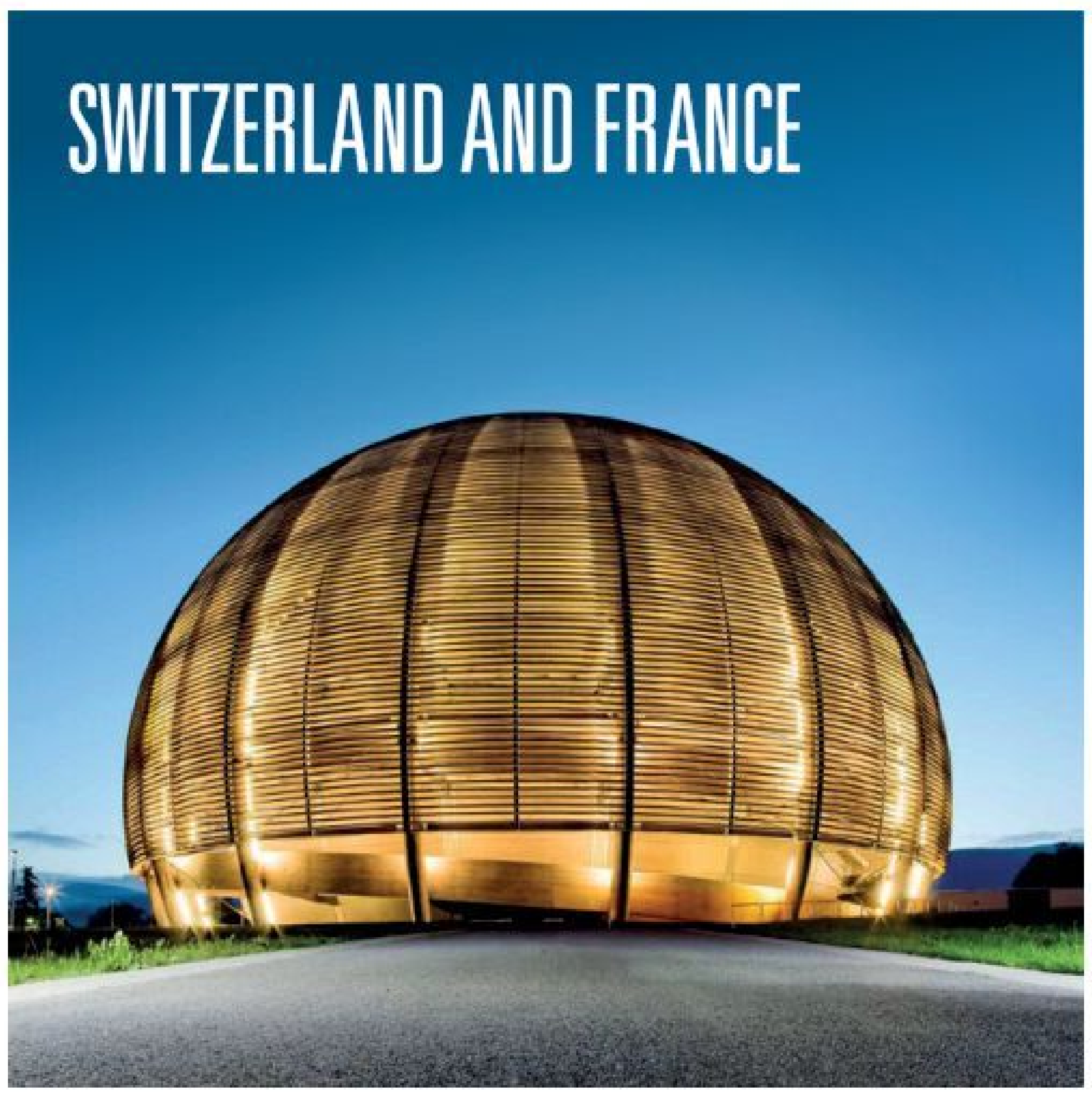

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